Energy SuperPower And Money

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Energy superpower

An energy superpower is a nation that supplies large amounts of energy resources (crude oil, natural gas, coal, uranium, etc.) to a significant number of other states, and therefore has the potential to influence world markets to gain a political or economic advantage. It is used to describe Russia, and has been used with other countries, such as Saudi Arabia, Canada, Venezuela, and Iran. The United States is said to be a potential energy superpower because of its large shale gas reserves.

Energy superpower status might be exercised, for example, by significantly influencing the price on global markets, or by withholding supplies. The status of "energy superpower" should not be confused with that of "superpower".

Russia's reserves of natural gas have helped give it the title of energy superpower. However, this status has been called into question by some. As Vladimir Milov, of the Carnegie Endowment for International Peace, says :

The "energy superpower" concept is an illusion with no basis in reality. Perhaps most dangerously, it doesn't recognize the mutual dependence between Russia and energy consumers. Because of political conflicts and declining production, future supply disruptions to Europe are likely. As a result, European gas companies may likely someday demand elimination of the take-or-pay conditions in their Russian contracts. This would threaten Gazprom's ability to borrow. Putin's attempt to use energy to increase Russian influence could backfire in the long run.

According to Manik Talwani, a geophysicist at Rice University, there are two countries that are most likely to join Saudi Arabia in attaining the status of oil superpower: Venezuela and Canada. Citing their enormous potential reserves (1.2 trillion potential barrels for Venezuela and 1.75 trillion for Canada's oil sands), Talwani believes that they have the reserves to become energy superpowers in the next few decades as oil production declines elsewhere. However, as Talwani notes, both need US$100 billion or more to increase their production levels up to those of true energy superpowers.

In 2007, al-Qaeda announced a new strategy for fighting the United States. Rather than only targeting U.S. interests directly in an attempt to cripple it, al-Qaeda considers cutting off the supply of energy to the U.S. to be a high priority. As reported

after a failed 2006 attempt in Saudi Arabia: "A major supply disruption would send energy prices soaring. Had the Abqaiq attack been successful – guards fired on cars driven by the bombers, detonating the explosives inside – some experts say oil prices would have likely broken all records. A catastrophic hit could bring transportation and other parts of the U.S. and world economies to a standstill."

1973 oil crisis

The **1973 oil crisis** began in October 1973 when the members of the Organization of Arab Petroleum Exporting Countries proclaimed an oil embargo. The embargo was targeted at nations perceived as supporting Israel during the Yom Kippur War. The initial nations targeted were Canada, Japan, the Netherlands, the United Kingdom and the United States with the embargo also later extended to Portugal, Rhodesia and South Africa. By the end of the embargo in March 1974, the price of oil had risen from US$3 per barrel to nearly $12 globally; US prices were significantly higher. The embargo caused an oil crisis, or "shock", with many short- and long-term effects on global politics and the global economy. It was later called the "first oil shock", followed by the 1979 oil crisis, termed the "second oil shock."

The embargo was a response to American involvement in the 1973 Yom Kippur War. Six days after Egypt and Syria launched a surprise military campaign against Israel, the US supplied Israel with arms. In response to this, the Organization of Arab Petroleum Exporting Countries (OAPEC, consisting of the Arab members of OPEC plus Egypt and Syria) announced an oil embargo against Canada, Japan, the Netherlands, the United Kingdom and the United States.

The crisis had a major impact on international relations and created a rift within NATO. Some European nations and Japan sought to disassociate themselves from United States foreign policy in the Middle East to avoid being targeted by the boycott. Arab oil producers linked any future policy changes to peace between the belligerents. To address this, the Nixon Administration began multilateral negotiations with the combatants. They arranged for Israel to pull back from the Sinai Peninsula and the Golan Heights. By January 18, 1974, US Secretary of State Henry Kissinger had negotiated an Israeli troop withdrawal from parts of the Sinai Peninsula. The promise of a negotiated settlement between Israel and Syria was enough to convince Arab oil producers to lift the embargo in March 1974.

Independently, OAPEC members agreed to use their leverage over the world price-setting mechanism for oil to stabilize their incomes by raising world oil prices after the recent failure of negotiations with Western oil companies.

The embargo occurred at a time of rising petroleum consumption by industrialized countries and coincided with a sharp increase in oil imports by the world's largest oil consumer, the United States. In the aftermath, targeted countries initiated a wide variety of policies to contain their future dependency.

The 1973 "oil price shock", with the accompanying 1973–74 stock market crash, was regarded as the first discrete event since the Great Depression to have a persistent effect on the US economy.

The embargo's success demonstrated Saudi Arabia's diplomatic and economic power. It was the largest oil exporter and a politically and religiously conservative kingdom.

US oil production decline

In 1970, US oil production started to decline, exacerbating the embargo's impact. Following this, Nixon named James E. Akins as US Ambassador to Saudi Arabia to audit US production capacity. The confidential results were alarming—no spare capacity was available and production could only decrease.

The oil embargo had little effect on overall supply, according to Akins.

The Organization of the Petroleum Exporting Countries (OPEC), which then comprised 12 countries, including Iran, seven Arab countries (Iraq, Kuwait, Libya, Qatar, Saudi Arabia and the United Arab Emirates), plus Venezuela, Indonesia, Nigeria and Ecuador, was formed at a Baghdad conference on September 14, 1960. OPEC was organized to resist pressure by the "Seven Sisters" (seven large, Western oil companies) to reduce oil prices.

At first, OPEC operated as an informal bargaining unit for resource-rich third-world countries. OPEC confined its activities to gaining a larger share of the profits generated by oil companies and greater control over member production levels. In the early 1970s it began to exert economic and political strength; the oil companies and importing nations suddenly faced a unified exporter bloc.

On August 15, 1971, the United States unilaterally pulled out of the Bretton Woods Accord. The US abandoned the Gold Exchange Standard whereby the value of the dollar had been pegged to the price of gold and all other currencies were pegged to the dollar, whose value was left to "float" (rise and fall according to market demand). Shortly thereafter, Britain followed, floating the pound sterling. The other

industrialized nations followed suit with their respective currencies. Anticipating that currency values would fluctuate unpredictably for a time, the industrialized nations increased their reserves (by expanding their money supplies) in amounts far greater than before. The result was a depreciation of the dollar and other industrialized nations' currencies. Because oil was priced in dollars, oil producers' real income decreased. In September 1971, OPEC issued a joint communiqué stating that, from then on, they would price oil in terms of a fixed amount of gold.

This contributed to the "Oil Shock". After 1971, OPEC was slow to readjust prices to reflect this depreciation. From 1947 to 1967, the dollar price of oil had risen by less than two percent per year. Until the oil shock, the price had also remained fairly stable versus other currencies and commodities. OPEC ministers had not developed institutional mechanisms to update prices in sync with changing market conditions, so their real incomes lagged. The substantial price increases of 1973–1974 largely returned their prices and corresponding incomes to Bretton Woods levels in terms of commodities such as gold.

On October 6, 1973, Syria and Egypt, with support from other Arab nations, launched a surprise attack on Israel, on Yom Kippur. This renewal of hostilities in the Arab–Israeli conflict released the underlying economic pressure on oil prices. At the time, Iran was the world's second-largest oil exporter and a close US ally. Weeks later, the Shah of Iran said in an interview: "Of course [the price of oil] is going to rise... Certainly! And how!... You've [Western nations] increased the price of the wheat you sell us by 300 percent, and the same for sugar and cement... You buy our crude oil and sell it back to us, refined as petrochemicals, at a hundred times the price you've paid us... It's only fair that, from now on, you should pay more for oil. Let's say ten times more."

On October 12, 1973, US president Richard Nixon authorized Operation Nickel Grass, a strategic airlift to deliver weapons and supplies to Israel, after the Soviet Union began sending arms to Syria and Egypt.

In response to American aid to Israel, on October 16, 1973, OPEC raised the posted price of oil by 70%, to $5.11 a barrel. The following day, oil ministers agreed to the embargo, a cut in production by five percent from September's output and to continue to cut production in five percent monthly increments until their economic and political objectives were met. On October 19, Nixon requested Congress to appropriate $2.2 billion in emergency aid to Israel, including $1.5 billion in outright grants. George Lenczowski notes, "Military supplies did not exhaust Nixon's eagerness to prevent Israel's collapse...This [$2.2 billion] decision triggered a collective OPEC response." Libya immediately announced it would embargo oil shipments to the United States. Saudi Arabia and the other Arab oil-producing states

joined the embargo on October 20, 1973. At their Kuwait meeting, OAPEC proclaimed the embargo that curbed exports to various countries and blocked all oil deliveries to the US as a "principal hostile country".

Price increases were also imposed greatly. Since short-term oil demand is inelastic, immediate demand falls little when the price rises. Thus, market prices rose from $3 per barrel to $12 per barrel to reduce demand to the new, lower level of supply. The world financial system, which was already under pressure from the Bretton Woods breakdown, was set on a path of recessions and inflation that persisted until the early 1980s, with oil prices remaining elevated until 1986.

Over the long term, the oil embargo changed the nature of policy in the West towards increased exploration, alternative energy research, energy conservation and more restrictive monetary policy to better fight inflation.

Chronology

- January 1973—The 1973–74 stock market crash commences as a result of inflation pressure and the collapsing monetary system.
- August 23, 1973—In preparation for the Yom Kippur War, Saudi king Faisal and Egyptian president Anwar Sadat meet in Riyadh and secretly negotiate an accord whereby the Arabs will use the "oil weapon" as part of the military conflict.
- October 6—Egypt and Syria attack Israeli-occupied lands in the Sinai Peninsula and Golan Heights on Yom Kippur, starting the 1973 Arab–Israeli War.
- Night of October 8—Israel goes on full nuclear alert. Kissinger is notified on the morning of October 9. United States begins to resupply Israel.
- October 8–10—OPEC negotiations with major oil companies to revise the 1971 Tehran price agreement fail.
- October 12—The United States initiates Operation Nickel Grass, a strategic airlift to provide replacement weapons and supplies to Israel. This followed similar Soviet moves to supply the Arab side.
- October 16—Saudi Arabia, Iran, Iraq, Abu Dhabi, Kuwait and Qatar raise posted prices by 17% to $3.65 per barrel and announce production cuts.
- October 17—OAPEC oil ministers agree to use oil to influence the West's support of Israel. They recommended an embargo against non-complying states and mandated export cuts.
- October 19—Nixon requests Congress to appropriate $2.2 billion in emergency aid to Israel, which triggers a collective Arab response. Libya immediately

proclaims an embargo on oil exports to the US. Saudi Arabia and other Arab oil-producing states follow the next day.
- October 26—The Yom Kippur War ends.
- November 5—Arab producers announce a 25% output cut. A further 5% cut is threatened.
- November 23—The Arab embargo is extended to Portugal, Rhodesia and South Africa.
- November 27—Nixon signs the Emergency Petroleum Allocation Act authorizing price, production, allocation and marketing controls.
- December 9—Arab oil ministers agree to another five percent production cut for non-friendly countries in January 1974.
- December 25—Arab oil ministers cancel the January output cut. Saudi oil minister Ahmed Zaki Yamani promises a ten percent OPEC production rise.
- January 7–9, 1974—OPEC decides to freeze prices until April 1.
- January 18—Israel signs a withdrawal agreement to pull back to the east side of the Suez Canal.
- February 11—Kissinger unveils the Project Independence plan for US energy independence.
- February 12–14—Progress in Arab-Israeli disengagement triggers discussion of oil strategy among the heads of state of Algeria, Egypt, Syria and Saudi Arabia.
- March 5—Israel withdraws the last of its troops from the west side of the Suez Canal.
- March 17—Arab oil ministers, with the exception of Libya, announce the end of the US embargo.
- May 31—Diplomacy by Kissinger produces a disengagement agreement on the Syrian front.
- December 1974—The 1973–74 stock market crash ends.

The effects of the embargo were immediate. OPEC forced oil companies to increase payments drastically. The price of oil quadrupled by 1974 to nearly US$12 per barrel (75 US$/m^3).

This price increase had a dramatic effect on oil exporting nations, for the countries of the Middle East who had long been dominated by the industrial powers seen to have taken control of a vital commodity. The oil-exporting nations began to accumulate vast wealth.

Some of the income was dispensed in the form of aid to other underdeveloped nations whose economies had been caught between higher oil prices and lower prices for their own export commodities, amid shrinking Western demand. Much went for arms

purchases that exacerbated political tensions, particularly in the Middle East. Saudi Arabia spent over 100 billion dollars in the ensuing decades for helping spread its fundamentalist interpretation of Islam, known as Wahhabism, throughout the world, via religious charities such al-Haramain Foundation, which often also distributed funds to violent Sunni extremist groups such as Al-Qaeda and the Taliban.

Control of oil became known as the "oil weapon." It came in the form of an embargo and production cutbacks from the Arab states. The weapon was aimed at the United States, Great Britain, Canada, Japan and the Netherlands. These target governments perceived that the intent was to push them towards a more pro-Arab position. Production was eventually cut by 25%. However, the affected countries did not undertake dramatic policy changes.

In the United States, scholars argue that there already existed a negotiated settlement based on equality between both parties prior to 1973. The possibility that the Middle East could become another superpower confrontation with the USSR was of more concern to the US than oil. Further, interest groups and government agencies more worried about energy were no match for Kissinger's dominance. In the US production, distribution and price disruptions "have been held responsible for recessions, periods of excessive inflation, reduced productivity, and lower economic growth."

The embargo had a negative influence on the US economy by causing immediate demands to address the threats to U.S. energy security. On an international level, the price increases changed competitive positions in many industries, such as automobiles. Macroeconomic problems consisted of both inflationary and deflationary impacts. The embargo left oil companies searching for new ways to increase oil supplies, even in rugged terrain such as the Arctic. Finding oil and developing new fields usually required five to ten years before significant production.

OPEC-member states raised the prospect of nationalization of oil company holdings. Most notably, Saudi Arabia nationalized Aramco in 1980 under the leadership of Saudi oil minister Ahmed Zaki Yamani. As other OPEC nations followed suit, the cartel's income soared. Saudi Arabia undertook a series of ambitious five-year development plans. The biggest began in 1980, funded at $250 billion. Other cartel members also undertook major economic development programs.

US retail price gas prices rose from a national average of 38.5 cents in May 1973 to 55.1 cents in June 1974. State governments requested citizens not to put up Christmas lights. Oregon banned Christmas and commercial lighting altogether. Politicians called for a national gas rationing program. Nixon requested gasoline stations to voluntarily not sell gasoline on Saturday nights or Sundays; 90% of owners complied, which produced long queues.

The embargo was not uniform across Europe. Of the nine members of the European Economic Community (EEC), the Netherlands faced a complete embargo, the UK and France received almost uninterrupted supplies (having refused to allow America to use their airfields and embargoed arms and supplies to both the Arabs and the Israelis), while the other six faced partial cutbacks. The UK had traditionally been an ally of Israel, and Harold Wilson's government supported the Israelis during the Six-Day War. His successor, Ted Heath, reversed this policy in 1970, calling for Israel to withdraw to its pre-1967 borders.

The EEC was unable to achieve a common policy during the first month of the War. It issued a statement on November 6, after the embargo and price rises had begun. It was widely viewed as pro-Arab supporting the Franco-British line on the war. OPEC duly lifted its embargo from all EEC members. The price rises had a much greater impact in Europe than the embargo.

Despite being relatively unaffected by the embargo, the UK nonetheless faced an oil crisis of its own—a series of strikes by coal miners and railroad workers over the winter of 1973–74 became a major factor in the change of government. Heath asked the British to heat only one room in their houses over the winter. The UK, Germany, Italy, Switzerland and Norway banned flying, driving and boating on Sundays. Sweden rationed gasoline and heating oil. The Netherlands imposed prison sentences for those who used more than their ration of electricity.

A few months later, the crisis eased. The embargo was lifted in March 1974 after negotiations at the Washington Oil Summit, but the effects lingered throughout the 1970s. The dollar price of energy increased again the following year, amid the weakening competitive position of the dollar in world markets.

Price controls exacerbated the crisis in the US. The system limited the price of "old oil" (that which had already been discovered) while allowing newly discovered oil to be sold at a higher price to encourage investment. Predictably, old oil was withdrawn from the market, creating greater scarcity. The rule also discouraged development of alternative energies. The rule had been intended to promote oil exploration. Scarcity was addressed by rationing (as in many countries). Motorists faced long lines at gas stations beginning in summer 1972 and increasing by summer 1973.

In 1973, Nixon named William E. Simon as the first Administrator of the Federal Energy Office, a short-term organization created to coordinate the response to the embargo. Simon allocated states the same amount of domestic oil for 1974 that each had consumed in 1972, which worked for states whose populations were not increasing. In other states, lines at gasoline stations were common. The American

Automobile Association reported that in the last week of February 1974, 20% of American gasoline stations had no fuel.

Odd–even rationing allowed vehicles with license plates having an odd number as the last digit (or a vanity license plate) to buy gas only on odd-numbered days of the month, while others could buy only on even-numbered days.

In some states, a three-color flag system was used to denote gasoline availability at service stations—green for unrationed availability, yellow for restricted/rationed sales and red for out of stock.

Rationing led to violent incidents, when truck drivers chose to strike for two days in December 1973 over the limited supplies Simon had allocated for their industry. In Pennsylvania and Ohio, non-striking truckers were shot at by striking truckers, and in Arkansas, trucks of non-strikers were attacked with bombs.

America had controlled the price of natural gas since the 1950s. With the inflation of the 1970s, the price was too low to encourage the search for new reserves. America's natural gas reserves dwindled from 237 trillion in 1974 to 203 trillion in 1978. The price controls were not changed despite president Gerald Ford's repeated requests to Congress.

To help reduce consumption, in 1974 a national maximum speed limit of 55 mph (about 88 km/h) was imposed through the Emergency Highway Energy Conservation Act. Development of the Strategic Petroleum Reserve began in 1975, and in 1977 the cabinet-level Department of Energy was created, followed by the National Energy Act of 1978. On November 28, 1995, Bill Clinton signed the National Highway Designation Act, ending the federal 55 mph (89 km/h) speed limit, allowing states to restore their prior maximum speed limit.

Year-round daylight saving time was implemented from January 6, 1974, to October 27, 1975, with a break between October 27, 1974 and February 23, 1975, when the country observed standard time. The move spawned significant criticism because it forced many children to travel to school before sunrise. The prior rules were restored in 1976.

The crisis prompted a call to conserve energy, most notably a campaign by the Advertising Council using the tagline "Don't Be Fuelish". Many newspapers carried advertisements featuring cut-outs that could be attached to light switches, reading "Last Out, Lights Out: Don't Be Fuelish."

By 1980, domestic luxury cars with a 130-inch (3.3 m) wheelbase and gross weights averaging 4,500 pounds (2,041 kg) were no longer made. The automakers had begun phasing out the traditional front engine/rear wheel drive layout in compact cars in favor of lighter front engine/front wheel drive designs. A higher percentage of cars offered more efficient 4-cylinder engines. Domestic auto makers also began offering more fuel efficient diesel powered passenger cars as well.

Though not regulated by the new legislation, auto racing groups voluntarily began conserving. In 1974, the 24 Hours of Daytona was cancelled and NASCAR reduced all race distances by 10%; the 12 Hours of Sebring race was cancelled.

In 1976, Congress created the Weatherization Assistance Program to help low-income homeowners and renters reduce their demand for heating and cooling through better insulation.

The energy crisis led to greater interest in renewable energy, nuclear power and domestic fossil fuels. According to Peter Grossman, American energy policies since the crisis have been dominated by crisis-mentality thinking, promoting expensive quick fixes and single-shot solutions that ignore market and technology realities. He wrote that instead of providing stable rules that support basic research while leaving plenty of scope for entrepreneurship and innovation, congresses and presidents have repeatedly backed policies which promise solutions that are politically expedient, but whose prospects are doubtful.

The Brazilian government implemented its "Proálcool" (pro-alcohol) project in 1975 that mixed ethanol with gasoline for automotive fuel.

Israel was one of the few countries unaffected by the embargo, since it could extract sufficient oil from the Sinai. But to supplement Israel's over-taxed power grid, Harry Zvi Tabor, the father of Israel's solar industry, developed the prototype for a solar water heater now used in over 90% of Israeli homes.

The crisis was a major factor in shifting Japan's economy away from oil-intensive industries. Investment shifted to industries such as electronics. Japanese auto makers also benefited from the crisis. Increased fuel costs allowed their small, fuel-efficient models to gain market share from the "gas-guzzling" American competition. This triggered a drop in American auto sales that lasted into the 1980s.

Western central banks decided to sharply cut interest rates to encourage growth, deciding that inflation was a secondary concern. Although this was the orthodox macroeconomic prescription at the time, the resulting stagflation surprised economists and central bankers. The policy is now considered by some to have deepened and

lengthened the adverse effects of the embargo. Recent research claims that in the period after 1985 the economy became more resilient to energy price increases.

The price shock created large current account deficits in oil-importing economies. A petrodollar recycling mechanism was created, through which OPEC surplus funds were channeled through the capital markets to the West to finance the current account deficits. The functioning of this mechanism required the relaxation of capital controls in oil-importing economies. It marked the beginning of an exponential growth of Western capital markets.

Many in the public remain suspicious of oil companies, believing they profiteered, or even colluded with OPEC. In 1974, seven of the fifteen top Fortune 500 companies were oil companies, falling to four in 2014.

International relations

United States

America's Cold War policies suffered a major blow from the embargo. They had focused on China and the Soviet Union, but the latent challenge to US hegemony coming from the third world became evident.

In 2004, declassified documents revealed that the U.S. was so distraught by the rise in oil prices and being challenged by under-developed countries that they briefly considered military action to forcibly seize Middle Eastern oilfields in late 1973. Although no explicit plan was mentioned, a conversation between U.S. Secretary of Defense James Schlesinger and British Ambassador to the United States Lord Cromer revealed Schlesinger had told him that "it was no longer obvious to him that the U.S. could not use force." British Prime Minister Edward Heath was so worried by this prospect that he ordered a British intelligence estimate of U.S. intentions, which concluded America "might consider it could not tolerate a situation in which the U.S. and its allies were at the mercy of a small group of unreasonable countries," and that they would prefer a rapid operation to seize oilfields in Saudi Arabia and Kuwait, and possibly Abu Dhabi in military action was decided upon. Although the Soviet response to such an act would likely not involve force, intelligence warned "the American occupation would need to last 10 years as the West developed alternative energy sources, and would result in the ‘total alienation’ of the Arabs and much of the rest of the Third World."

NATO

Western Europe began switching from pro-Israel to more pro-Arab policies. This change strained the Western alliance. The US, which imported only 12% of its oil from the Middle East (compared with 80% for the Europeans and over 90% for Japan), remained staunchly committed to Israel. The percentage of U.S. oil which comes from the nations bordering the Persian Gulf remained steady over the decades, with a figure of a little more than 10% in 2008.

With the embargo in place, many developed countries altered their policies regarding the Arab-Israeli conflict. These included the UK, which refused to allow the United States to use British bases and Cyprusto airlift resupplies to Israel along with the rest of the members of the European Community.

Canada shifted towards a more pro-Arab position after displeasure was expressed towards Canada's mostly neutral position. "On the other hand, after the embargo the Canadian government moved quickly indeed toward the Arab position, despite its low dependence on Middle Eastern oil".

Japan

Although lacking historical connections to the Middle East, Japan was the country most dependent on Arab oil. 71% of its imported oil came from the Middle East in 1970. On November 7, 1973, the Saudi and Kuwaiti governments declared Japan a "nonfriendly" country to encourage it to change its noninvolvement policy. It received a 5% production cut in December, causing a panic. On November 22, Japan issued a statement "asserting that Israel should withdraw from all of the 1967 territories, advocating Palestinian self-determination, and threatening to reconsider its policy toward Israel if Israel refused to accept these preconditions". By December 25, Japan was considered an Arab-friendly state.

Nonaligned nations

The oil embargo was announced roughly one month after a right-wing military coup in Chile led by General Augusto Pinochet toppled socialist president Salvador Allende on September 11, 1973. The response of the Nixon administration was to propose doubling arms sales. As a consequence, an opposing Latin American bloc

was organized and financed in part by Venezuelan oil revenues, which quadrupled between 1970 and 1975.

A year after the start of the embargo, the UN's nonaligned bloc passed a resolution demanding the creation of a "New International Economic Order" under which nations within the global South would receive a greater share of benefits derived from the exploitation of southern resources and greater control over their self-development.

Arab states

Prior to the embargo, the geo-political competition between the Soviet Union and the United States, in combination with low oil prices that hindered the necessity and feasibility of alternative energy sources, presented the Arab States with financial security, moderate economic growth, and disproportionate international bargaining power.

The oil shock disrupted the status quo relationships between Arab countries and the US and USSR. At the time, Egypt, Syria and Iraq were allied with the USSR, while Saudi Arabia, Turkey and Iran (plus Israel) aligned with the US. Vacillations in alignment often resulted in greater support from the respective superpowers.

When Anwar Sadat became president of Egypt in 1970, he dismissed Soviet specialists in Egypt and reoriented towards the US. Concerns over economic domination from increased Soviet oil production turned into fears of military aggression after the 1979 Soviet invasion of Afghanistan, turning the Persian Gulf states towards the US for security guarantees against Soviet military action.

The USSR's invasion of Afghanistan was only one sign of insecurity in the region, also marked by increased American weapons sales, technology, and outright military presence. Saudi Arabia and Iran became increasingly dependent on American security assurances to manage both external and internal threats, including increased military competition between them over increased oil revenues. Both states were competing for preeminence in the Persian Gulf and using increased revenues to fund expanded militaries. By 1979, Saudi arms purchases from the US exceeded five times Israel's.

In the wake of the 1979 Iranian Revolution the Saudis were forced to deal with the prospect of internal destabilization via the radicalism of Islamism, a reality which would quickly be revealed in the Grand Mosque seizure in Mecca
by Wahhabi extremists during November 1979, and a Shiite Muslim revolt in the oil rich Al-Hasa region of Saudi Arabia in December of the same year, which was known

as the 1979 Qatif Uprising. Saudi Arabia is a near absolute monarchy, an Arabic speaking country, and has a Sunni Muslim majority, while Persian speaking Iran since 1979 is an Islamist theocracy with a ShiiteMuslim majority, which explains the current hostility between Saudi Arabia and Iran.

In November 2010, Wikileaks leaked confidential diplomatic cables pertaining to the United States and its allies which revealed that the late Saudi King Abdullah urged the United States to attack Iran in order to destroy its potential nuclear weapons program, describing Iran as "a snake whose head should be cut off without any procrastination".

Automobile industry

Western Europe

After World War II, most West European countries taxed motor fuel to limit imports, and as a result most cars made in Europe were smaller and more economical than their American counterparts. By the late 1960s increasing incomes supported rising car sizes.

The oil crisis pushed West European car buyers away from larger, less economical cars. The most notable result of this transition was the rise in popularity of compact hatchbacks. The only notable small hatchbacks built in Western Europe before the oil crisis were the Peugeot 104, Renault 5 and Fiat 127. By the end of the decade, the market had expanded with the introduction of the Ford Fiesta, Opel Kadett(sold as the Vauxhall Astra in Great Britain), Chrysler Sunbeam and Citroën Visa.

Buyers looking for larger cars were increasingly drawn to medium-sized hatchbacks. Virtually unknown in Europe in 1973, by the end of the decade they were gradually replacing saloons as the mainstay of this sector. Between 1973 and 1980, medium-sized hatchbacks were launched across Europe: the Chrysler/Simca Horizon, Fiat Ritmo (Strada in the UK), Ford Escort MK3, Renault 14, Volvo 340 / 360, Opel Kadett, and Volkswagen Golf.

These cars were considerably more economical than the traditional saloons they were replacing, and attracted buyers who traditionally bought larger vehicles. Some 15 years after the oil crisis, hatchbacks dominated most European small and medium car markets, and had gained a substantial share of the large family car market.

United States

Before the energy crisis, large, heavy, and powerful cars were popular. By 1971, the standard engine in a Chevrolet Caprice was a 400-cubic inch (6.5 liter) V8. The wheelbase of this car was 121.5 inches (3,090 mm), and *Motor Trend*'s 1972 road test of the similar Chevrolet Impala achieved no more than 15 highway miles per gallon. In the fifteen years prior to the 1973 oil crisis, gasoline prices in the U.S. had lagged well behind inflation.

The crisis reduced the demand for large cars. Japanese imports, primarily the Toyota Corona, the Toyota Corolla, the Datsun B210, the Datsun 510, the Honda Civic, the Mitsubishi Galant (a captive import from Chrysler sold as the Dodge Colt), the Subaru DL, and later the Honda Accord all had four cylinder engines that were more fuel efficient than the typical American V8 and six cylinder engines. Japanese imports became mass-market leaders with unibody construction and front-wheel drive, which became de facto standards.

From Europe, the Volkswagen Beetle, the Volkswagen Fastback, the Renault 8, the Renault LeCar, and the Fiat Brava were successful. Detroit responded with the Ford Pinto, the Ford Maverick, the Chevrolet Vega, the Chevrolet Nova, the Plymouth Valiant and the Plymouth Volaré. American Motors sold its homegrown Gremlin, Hornet and Pacer models.

Some buyers lamented the small size of the first Japanese compacts, and both Toyota and Nissan (then known as Datsun) introduced larger cars such as the Toyota Corona Mark II, the Toyota Cressida, the Mazda 616 and Datsun 810, which added passenger space and amenities such as air conditioning, power steering, AM-FM radios, and even power windows and central locking without increasing the price of the vehicle. A decade after the 1973 oil crisis, Honda, Toyota and Nissan, affected by the 1981 voluntary export restraints, opened US assembly plants and established their luxury divisions (Acura, Lexus and Infiniti, respectively) to distinguish themselves from their mass-market brands.

Compact trucks were introduced, such as the Toyota Hilux and the Datsun Truck, followed by the Mazda Truck (sold as the Ford Courier), and the Isuzu-built Chevrolet LUV. Mitsubishi rebranded its Forteas the Dodge D-50 a few years after the oil crisis. Mazda, Mitsubishi and Isuzu had joint partnerships with Ford, Chrysler, and GM, respectively. Later the American makers introduced their domestic replacements (Ford Ranger, Dodge Dakota and the Chevrolet S10/GMC S-15), ending their captive import policy.

An increase in imported cars into North America forced General Motors, Ford and Chrysler to introduce smaller and fuel-efficient models for domestic sales. The Dodge Omni / Plymouth Horizon from Chrysler, the Ford Fiesta and the Chevrolet Chevette all had four-cylinder engines and room for at least four passengers by the late 1970s. By 1985, the average American vehicle moved 17.4 miles per gallon, compared to 13.5 in 1970. The improvements stayed even though the price of a barrel of oil remained constant at $12 from 1974 to 1979. Sales of large sedans for most makes (except Chrysler products) recovered within two model years of the 1973 crisis. The Cadillac DeVille and Fleetwood, Buick Electra, Oldsmobile 98, Lincoln Continental, Mercury Marquis, and various other luxury oriented sedans became popular again in the mid-1970s. The only full-size models that did not recover were lower price models such as the Chevrolet Bel Air and Ford Galaxie 500. Slightly smaller models such as the Oldsmobile Cutlass, Chevrolet Monte Carlo, Ford Thunderbird and various others sold well.

Economical imports succeeded alongside heavy, expensive vehicles. In 1976 Toyota sold 346,920 cars (average weight around 2,100 lbs), while Cadillac sold 309,139 cars (average weight around 5,000 lbs).

Federal safety standards, such as NHTSA Federal Motor Vehicle Safety Standard 215 (pertaining to safety bumpers), and compacts like the 1974 Mustang I were a prelude to the DOT "downsize" revision of vehicle categories. By 1977, GM's full-sized cars reflected the crisis. By 1979, virtually all "full-size" American cars had shrunk, featuring smaller engines and smaller outside dimensions. Chryslerended production of their full-sized luxury sedans at the end of the 1981 model year, moving instead to a full front-wheel drive lineup for 1982 .

OPEC soon lost its preeminent position, and in 1981, its production was surpassed by that of other countries. Additionally, its own member nations were divided. Saudi Arabia, trying to recover market share, increased production, pushing prices down, shrinking or eliminating profits for high-cost producers. The world price, which had peaked during the 1979 energy crisis at nearly $40 per barrel, decreased during the 1980s to less than $10 per barrel. Adjusted for inflation, oil briefly fell back to pre-1973 levels. This "sale" price was a windfall for oil-importing nations, both developing and developed.

The embargo encouraged new venues for energy exploration including Alaska, the North Sea, the Caspian Sea, and the Caucasus. Exploration in the Caspian Basin and Siberia became profitable. Cooperation changed into a far more adversarial

relationship as the USSR increased its production. By 1980 the Soviet Union had become the world's largest producer.

Part of the decline in prices and economic and geopolitical power of OPEC came from the move to alternate energy sources. OPEC had relied on price inelasticity to maintain high consumption, but had underestimated the extent to which conservation and other sources of supply would eventually reduce demand. Electricity generation from nuclear power and natural gas, home heating from natural gas, and ethanol-blended gasoline all reduced the demand for oil.

The drop in prices presented a serious problem for oil-exporting countries in northern Europe and the Persian Gulf. Heavily populated, impoverished countries, whose economies were largely dependent on oil—including Mexico, Nigeria, Algeria, and Libya—did not prepare for a market reversal that left them in sometimes desperate situations.

When reduced demand and increased production glutted the world market in the mid-1980s, oil prices plummeted and the cartel lost its unity. Mexico (a non-member), Nigeria, and Venezuela, whose economies had expanded in the 1970s, faced near-bankruptcy, and even Saudi Arabian economic power was significantly weakened. The divisions within OPEC made concerted action more difficult. As of 2015, OPEC had never approached its earlier dominance.

1973–74 stock market crash

The 1973–74 stock market crash caused a bear market between January 1973 and December 1974. Affecting all the major stock markets in the world, particularly the United Kingdom, it was one of the worst stock market downturns in modern history. The crash came after the collapse of the Bretton Woods system over the previous two years, with the associated 'Nixon Shock' and United States dollar devaluation under the Smithsonian Agreement. It was compounded by the outbreak of the 1973 oil crisis in October of that year. It was a major event of the 1970s recession.

In the 694 days between 11 January 1973 and 6 December 1974, the New York Stock Exchange's Dow Jones Industrial Average benchmark lost over 45% of its value, making it the seventh-worst bear marketin the history of the index. 1972 had been a good year for the DJIA, with gains of 15% in the twelve months. 1973 had been expected to be even better, with Time magazine reporting, just 3 days before the crash began, that it was 'shaping up as a gilt-edged year'. In the two years from 1972 to 1974, the American economy slowed from 7.2% real GDP growth to −2.1% contraction, while inflation (by CPI) jumped from 3.4% in 1972 to 12.3% in 1974.

Worse was the effect in the United Kingdom, and particularly on the London Stock Exchange's FT 30, which lost 73% of its value during the crash. From a position of 5.1% real GDP growth in 1972, the UK went into recession in 1974, with GDP falling by 1.1%. At the time, the UK's property market was going through a major crisis, and a secondary banking crisis forced the Bank of England to bail out a number of lenders. In the United Kingdom, the crash ended after the rent freeze was lifted on 19 December 1974, allowing a readjustment of property prices; over the following year, stock prices rose by 150%. The definitive market low for the FT30 Index (a forerunner of the FTSE100 today), came on 6 January 1975 when the index closed at 146 (having reached a nadir of 145.8 intra-day). The market then practically doubled in just over 3 months. However, unlike in the United States, inflation continued to rise, to 25% in 1975, giving way to the era of stagflation. The Hong Kong Hang Seng Index also fell from 1,800 in early 1973 to close to 300.

Out of the 20 largest percentage gains and losses in the DJIA, none occurred during this time period.

All the main stock indexes of the future G7 bottomed out between September and December 1974, having lost at least 34% of their value in nominal terms, and 43% in real terms. In all cases, the recovery was a slow process. Although West Germany's market was the fastest to recover, returning to the original nominal level within eighteen months, it did not return to the same real level until June 1985. The United Kingdom didn't return to the same market level until May 1987 (only a few months before the Black Monday crash), whilst the United States didn't see the same level in real terms until August 1993—over twenty years after the 1973–74 crash began.

The Hong Kong TVB series *The Greed of Man* storyline revolves around the market crash.

1980s oil glut

The 1980s oil glut was a serious surplus of crude oil caused by falling demand following the 1970s energy crisis. The world price of oil, which had peaked in 1980 at over US$35 per barrel (equivalent to $104 per barrel in 2008 dollars, when adjusted for inflation), fell in 1986 from $27 to below $10 ($60 to $22 in 2008 dollars). The glut began in the early 1980s as a result of slowed economic activity in industrial countries (due to the crises of the 1970s, especially in 1973 and 1979) and the energy conservation spurred by high fuel prices. The inflation-adjusted real 2004 dollar value of oil fell from an average of $78.2 in 1981 to an average of $26.8 per barrel in 1986.

In June 1981, The New York *Times* stated an "Oil glut! ... is here" and **Time Magazine** stated: "the world temporarily floats in a glut of oil", though the next week an article in *The New York Times* warned that the word "glut" was misleading, and that in reality, while temporary surpluses had brought down prices somewhat, prices were still well above pre-energy crisis levels. This sentiment was echoed in November 1981, when the CEO of Exxon Corp also characterized the glut as a temporary surplus, and that the word "glut" was an example of "our American penchant for exaggerated language". He wrote that the main cause of the glut was declining consumption. In the United States, Europe and Japan, oil consumption had fallen 13% from 1979 to 1981, due to "in part, in reaction to the very large increases in oil prices by the Organization of Petroleum Exporting Countries and other oil exporters", continuing a trend begun during the 1973 price increases.

After 1980, reduced demand and increased production produced a glut on the world market. The result was a six-year decline in the price of oil, which culminated by plunging more than half in 1986 alone.

Non-OPEC

During the 1980s, reliance on Middle East production dwindled as commercial exploration developed major non-OPEC oilfields in Siberia, Alaska, the North Sea, and the Gulf of Mexico, and the Soviet Union became the world's largest producer of oil. Smaller non-OPEC producers including Brazil, Egypt, India, Malaysia, and

Oman doubled their output between 1979 and 1985, to a total of 3 million barrels per day.

USA

In April 1979, Jimmy Carter signed an executive order which was to remove price controls from petroleum products by October 1981, so that prices would be wholly determined by the free market. Ronald Reagan signed an executive order on January 28, 1981, which enacted this reform immediately, allowing the free market to adjust oil prices in the US. This ended the withdrawal of old oil from the market and artificial scarcity, encouraging increased oil production. The US Oil Windfall profits tax was lowered in August 1981 and removed in 1988, ending disincentives to US oil producers. Additionally, Trans-Alaska Pipeline System began pumping oil in 1977. The Alaskan Prudhoe Bay Oil Field entered peak production, supplying 2 million bpd of crude oil in 1988, 25 percent of all U.S. oil production.

North Sea

Phillips Petroleum discovered oil in the Chalk Group at Ekofisk, in Norwegian waters in the central North Sea. Discoveries increased exponentially in the 1970s and 1980s, and new fields were developed throughout the continental shelf.

OPEC

From 1980 to 1986, OPEC decreased oil production several times and nearly in half, in an attempt to maintain oil's high prices. However, it failed to hold on to its preeminent position, and by 1981, its production was surpassed by non-OPEC countries . OPEC had seen its share of the world market drop to less than a third in 1985, from about half during the 1970s. In February 1982, the *Boston Globe* reported that OPEC's production, which had previously peaked in 1977, was at its lowest level since 1969. Non-OPEC nations were at that time supplying most of the West's imports.

OPEC's membership began to have divided opinions over what actions to take. In September 1985, Saudi Arabia became fed up with de facto propping up prices by lowering its own production in the face of high output from elsewhere in OPEC. In

1985, daily output was around 3.5 million bpd, down from around 10 million in 1981. During this period, OPEC members were supposed to meet production quotas in order to maintain price stability; however, many countries inflated their reserves to achieve higher quotas, cheated, or outright refused to accord with the quotas. In 1985, the Saudis tired of this behavior and decided to punish the undisciplined OPEC countries. The Saudis abandoned their role as swing producer and began producing at full capacity, creating a "huge surplus that angered many of their colleagues in OPEC". High-cost oil production facilities became less or even not profitable. Oil prices as a result fell to as low as $7 per barrel.

OPEC had relied on the price inelasticity of demand of oil to maintain high consumption, but underestimated the extent to which other sources of supply would become profitable as prices increased. Electricity generation from coal, nuclear power and natural gas; home heating from natural gas; and ethanol blended gasoline all reduced the demand for oil.

New passenger car fuel economy in the US rose from 17 mpg in 1978 to more than 22 mpg in 1982, an increase of more than 30 percent.

The US imported 28 percent of its oil in 1982 and 1983, down from 46.5 percent in 1977, due to lower consumption.

The 1986 oil price collapse benefited oil-consuming countries such as the United States, Japan, Europe, and Third World nations, but represented a serious loss in revenue for oil-producing countries in northern Europe, the Soviet Union, and OPEC.

In 1981, before the brunt of the glut, *Time Magazine* wrote that in general, "A glut of crude causes tighter development budgets" in some oil-exporting nations. Mexico had an economic and debt crisis in 1982. The Venezuelan economy contracted and inflation levels (consumer price inflation) rose, remaining between 6 and 12% from 1982 to 1986. Even Saudi Arabian economic power was significantly weakened.

Iraq had fought a long and costly war against Iran, and had particularly weak revenues. It was upset by Kuwait contributing to the glut and allegedly pumping oil from the Rumaila field below their common border. Iraq invaded Kuwait in 1990, planning to increase reserves and revenues and cancel the debt, resulting in the first Gulf War.

The USSR had become a major oil producer before the glut. The drop of oil prices contributed to the nation's final collapse.

In the US, domestic exploration and the number of active drilling rigs were cut dramatically. In late 1985, there were nearly 2,300 rigs drilling wells in the USA; a year later, there were barely 1,000. The number of petroleum producers in United States decreased from 11,370 in 1985 to 5,231 in 1989, according to data from the Independent Petroleum Association of America. Oil producers held back on the search for new oilfields for fear of losing on their investments. In May 2007, companies like ExxonMobil were not making nearly the investment in finding new oil that they did in 1981.

Canada responded to high energy prices in the 1970s with the National Energy Program (NEP) in 1980. This program was in place until 1985.

Energy security

Energy security is the association between national security and the availability of natural resources for energy consumption. Access to (relatively) cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities.

Renewable resources and significant opportunities for energy efficiency exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency, and technological diversification of energy sources, would result in significant energy security and economic benefits.

The modern world relies on a vast energy supply to fuel everything from transportation to communication, to security and health delivery systems. Perhaps most alarmingly, peak oil expert Michael Rupperthas claimed that for every calorie of food produced in the industrial world, ten calories of oil and gas energy are invested in the forms of fertilizer, pesticide, packaging, transportation, and running farm equipment. Energy plays an important role in the national security of any given country as a fuel to power the economic engine. Some sectors rely on energy more heavily than others; for example, the Department of Defense relies on petroleum for approximately 77% of its energy needs. Threats to **energy security** include the political instability of several energy producing countries, the manipulation of energy supplies, the competition over energy sources, attacks on supply infrastructure, as well as accidents, natural disasters, terrorism, and reliance on foreign countries for oil.

Foreign oil supplies are vulnerable to unnatural disruptions from in-state conflict, exporters' interests, and non-state actors targeting the supply and transportation of oil resources. The political and economic instability caused by war or other factors such as strike action can also prevent the proper functioning of the energy industry in a supplier country. For example, the nationalization of oil in Venezuela has triggered strikes and protests in which Venezuela's oil production rates have yet to recover. Exporters may have political or economic incentive to limit their foreign sales or cause disruptions in the supply chain. The 1973 oil embargo against the United States is a historical example in which oil supplies were cut off to the United States due to U.S. support of Israel during the Yom Kippur War. This has been done to apply pressure during economic negotiations—such as during the 2007 Russia–Belarus energy dispute. Terrorist attacks targeting oil facilities, pipelines, tankers, refineries,

and oil fields are so common they are referred to as "industry risks". Infrastructure for producing the resource is extremely vulnerable to sabotage. One of the worst risks to oil transportation is the exposure of the five ocean chokepoints, like the Iranian-controlled Strait of Hormuz. Anthony Co desman, a scholar at the Center for Strategic and International Studies in Washington, D.C., warns, "It may take only one asymmetric or conventional attack on a Ghawar Saudi oil field or tankers in the Strait of Hormuz to throw the market into a spiral."

New threats to energy security have emerged in the form of the increased world competition for energy resources due to the increased pace of industrialization in countries such as India and China, as well as due to the increasing consequences of climate change. Although still a minority concern, the possibility of price rises resulting from the peaking of world oil production is also starting to attract the attention of at least the French government. Increased competition over energy resources may also lead to the formation of security compacts to enable an equitable distribution of oil and gas between major powers. However, this may happen at the expense of less developed economies. The Group of Five, precursors to the G8, first met in 1975 to coordinate economic and energy policies in the wake of the 1973 Arab oil embargo, a rise in inflation and a global economic slowdown. NATO leaders meeting in Bucharest Romania, in April 2008, may discuss the possibility of using the military alliance "as an instrument of energy security". One of the possibilities include placing troops in the Caucasus region to police oil and gas pipelines.

Long-term measures to increase energy security center on reducing dependence on any one source of imported energy, increasing the number of suppliers, exploiting native fossil fuel or renewable energyresources, and reducing overall demand through energy conservation measures. It can also involve entering into international agreements to underpin international energy trading relationships, such as the Energy Charter Treaty in Europe. All the concern coming from security threats on oil sources long term security measures will help reduce the future cost of importing and exporting fuel into and out of countries without having to worry about harm coming to the goods being transported.

The impact of the 1973 oil crisis and the emergence of the OPEC cartel was a particular milestone that prompted some countries to increase their energy security. Japan, almost totally dependent on imported oil, steadily introduced the use of natural gas, nuclear power, high-speed mass transit systems, and implemented energy conservation measures. The United Kingdom began exploiting North Sea oil and gas reserves, and became a net exporter of energy into the 2000s.

In other countries energy security has historically been a lower priority. The United States, for example, has continued to increase its dependency on imported oil

although, following the oil price increases since 2003, the development of biofuels has been suggested as a means of addressing this.

Increasing energy security is also one of the reasons behind a block on the development of natural gas imports in Sweden. Greater investment in native renewable energy technologies and energy conservation is envisaged instead. India is carrying out a major hunt for domestic oil to decrease its dependency on OPEC, while Iceland is well advanced in its plans to become energy independent by 2050 through deploying 100% renewable energy.

Petroleum, otherwise known as "crude oil", has become the resource most used by countries all around the world including Russia, China (actually, China is mostly dependent on coal (70.5% in 2010)) and the United States of America. With all the oil wells located around the world energy security has become a main issue to ensure the safety of the petroleum that is being harvested. In the middle east oil fields become main targets for sabotage because of how heavily countries rely on oil. Many countries hold strategic petroleum reserves as a buffer against the economic and political impacts of an energy crisis. All 28 members of the International Energy Agency hold a minimum of 90 days of their oil imports, for example.

The value of such reserves was demonstrated by the relative lack of disruption caused by the 2007 Russia-Belarus energy dispute, when Russia indirectly cut exports to several countries in the European Union.

Due to the theories in peak oil and need to curb demand, the United States military and Department of Defense had made significant cuts, and have been making a number of attempts to come up with more efficient ways to use oil.

Compared to petroleum, reliance on imported natural gas creates significant short-term vulnerabilities. Many European countries saw an immediate drop in supply when Russian gas supplies were halted during the Russia-Ukraine gas dispute in 2006.

Natural gas has been a viable source of energy in the world. Consisting of mostly methane, natural gas is produced using two methods: biogenic and thermogenic. Biogenic gas comes from methanogenicorganisms located in marshes and landfills, whereas thermogenic gas comes from the anaerobic decay of organic matter deep under the Earth's surface. Russia is the current leading country in production of natural gas.

One of the biggest problems currently facing natural gas providers is the ability to store and transport it. With its low density, it is difficult to build enough pipelines in North America to transport sufficient natural gas to match demand. These pipelines

are reaching near capacity and even at full capacity do not produce the amount of gas needed.

Uranium for nuclear power is mined and enriched in diverse and "stable" countries. These include Canada (23% of the world's total in 2007), Australia (21%), Kazakhstan (16%) and more than 10 other countries. Uranium is mined and fuel is manufactured significantly in advance of need. Nuclear fuel is considered by some to be a relatively reliable power source, being more common in the Earth's crust than tin, mercury or silver, though a debate over the timing of peak uranium does exist.

Nuclear power reduces carbon emissions. Although a very viable resource, nuclear power can be a controversial solution because of the risks associated with it. Another factor in the debate with nuclear power is that many people or companies simply do not want any nuclear energy plant or radioactive waste near them.

Currently, nuclear power provides 13% of the world's total electricity. The most notable use of nuclear power within the United States is in U.S. Navy aircraft carriers, cruisers, and submarines, which have been exclusively nuclear-powered for several decades. These classes of ship provide the core of the Navy's power, and as such are the single most noteworthy application of nuclear power in that country.

The deployment of renewable technologies usually increases the diversity of electricity sources and, through local generation, contributes to the flexibility of the system and its resistance to central shocks. For those countries where growing dependence on imported gas is a significant energy security issue, renewable technologies can provide alternative sources of electric power as well as displacing electricity demand through direct heat production. Renewable biofuels for transport represent a key source of diversification from petroleum products.

As the resources that have been so crucial to survival in the world to this day start declining in numbers, countries will begin to realize that the need for renewable fuel sources will be as vital as ever. With the production of new types of energy, including solar, geothermal, hydro-electric, biofuel, and wind power. With the amount of solar energy that hits the world in one hour there is enough energy to power the world for one year. With the addition of solar panels all around the world a little less pressure is taken off the need to produce more oil.

Geothermal can potentially lead to other sources of fuel, if companies would take the heat from the inner core of the earth to heat up water sources we could essentially use the steam creating from the heated water to power machines, this option is one of the cleanest and efficient options. Hydro-electric which has been incorporated into many of the dams around the world, produces a lot of energy, and is very easy to produce

the energy as the dams control the water that is allowed through seams which power turbines located inside of the dam. Biofuels have been researched using many different sources including ethanol and algae, these options are substantially cleaner than the consumption of petroleum. "Most life cycle analysis results for perennial and ligno-cellulosic crops conclude that biofuels can supplement anthropogenic energy demands and mitigate green house gas emissions to the atmosphere". Using oil to fuel transportation is a major source of green house gases, any one of these developments could replace the energy we derive from oil.

Petroleum politics

Petroleum politics have been an increasingly important aspect of diplomacy since the rise of the petroleum industry in the Middle East in the early 20th century. As competition continues for a vital resource, the strategic calculations of major and minor countries alike place prominent emphasis on the pumping, refining, transport, sale and use of petroleum products. However, international climate policy and unconventional oil and gas developments may change the balance of power between petroleum exporting and importing countries with major negative implications expected for the exporting states.

Quota agreements

The Achnacarry Agreement or "As-Is Agreement" was an early attempt to restrict petroleum production, signed in Scotland on 17 September 1928. The discovery of the East Texas Oil Field in the 1930s led to a boom in production that caused prices to fall, leading the Railroad Commission of Texas to control production. The Commission retained *de facto* control of the market until the rise of OPEC in the 1970s.

The Anglo-American Petroleum Agreement of 1944 tried to extend these restrictions internationally but was opposed by the industry in the United States and so Franklin Roosevelt withdrew from the deal.

Venezuela was the first country to move towards the establishment of OPEC by approaching Iran, Gabon, Libya, Kuwait and Saudi Arabia in 1949, but OPEC was not set up until 1960, when the United States forced import quotas on Venezuelan and Persian Gulf oil in order to support the Canadian and Mexican oil industries .OPEC first wielded its power with the 1973 oil embargo against the United States and Western Europe.

Oil and international conflict

The term "petro-aggression" has been used to describe the tendency of oil-rich states to instigate international conflicts. There are many examples including: Iraq's invasion of Iran and Kuwait; Libya's repeated incursions into Chad in the 1970s and 1980s; Iran's long-standing suspicion of Western powers. Some scholars have also suggested that oil-rich states are frequently the targets of "resource wars."

Peak oil

In 1956, a Shell geophysicist named M. King Hubbert accurately predicted that U.S. oil production would peak in 1970.

In June 2006, former U.S. president Bill Clinton said in a speech,

"We may be at a point of peak oil production. You may see $100 a barrel oil in the next two or three years, but what still is driving this globalization is the idea that is you cannot possibly get rich, stay rich and get richer if you don't release more greenhouse gases into the atmosphere. That was true in the industrial era; it is simply factually not true. What is true is that the old energy economy is well organized, financed and connected politically."

In a 1999 speech, Dick Cheney, the US Vice President and former CEO of Halliburton (one of the world's largest energy services corporations), said,

"By some estimates there will be an average of two per cent annual growth in global oil demand over the years ahead along with conservatively a three per cent natural decline in production from existing reserves. That means by 2010 we will need on the order of an additional fifty million barrels a day. So where is the oil going to come from?....While many regions of the world offer great oil opportunities, the Middle East with two thirds of the world's oil and the lowest cost, is still where the prize ultimately lies, even though companies are anxious for greater access there, progress continues to be slow."

Cheney went on to argue that the oil industry should become more active in politics:

"Oil is the only large industry whose leverage has not been all that effective in the political arena. Textiles, electronics, agriculture all seem often to be more influential.

Our constituency is not only oilmen from Louisiana and Texas, but software writers in Massachusetts and specialty steel producers in Pennsylvania. I am struck that this industry is so strong technically and financially yet not as politically successful or influential as are often smaller industries. We need to earn credibility to have our views heard."

Pipeline diplomacy in the Caspian Sea area

The Baku–Tbilisi–Ceyhan pipeline was built to transport crude oil and the Baku-Tbilisi-Erzurum pipeline was built to transport natural gas from the western side (Azerbaijani sector) of the Caspian Sea to the Mediterranean Sea bypassing Russian pipelines and thus Russian control. Following the construction of the pipelines, the United States and the European Union proposed extending them by means of the proposed Trans-Caspian Oil Pipeline and the Trans-Caspian Gas Pipeline under the Caspian Sea to oil and gas fields on the eastern side (Kazakhstan and Turkmenistan sectors) of the Caspian Sea. In 2007, Russia signed agreements with Turkmenistan and Kazakhstan to connect their oil and gas fields to the Russian pipeline system effectively killing the undersea route.

China has completed the Kazakhstan–China oil pipeline from the Kazakhstan oil fields to the Chinese Alashankou-Dushanzi Crude Oil Pipeline in China. China is also working on the Kazakhstan-China gas pipeline from the Kazakhstan gas fields to the Chinese West-East Gas Pipeline in China.

Politics of oil nationalization

Several countries have nationalised foreign-run oil businesses, often failing to compensate investors. Enrique Mosconi, the director of the Argentine state owned oil company *Yacimientos Petrolíferos Fiscales*(YPF, which was the first state owned oil company in the world, preceding the French *Compagnie française des pétroles* (CFP, French Company of Petroleums), created in 1924 by the conservative Raymond Poincaré), advocated oil nationalization in the late 1920s among Latin American countries. The latter was achieved in Mexico during Lázaro Cárdenas's rule, with the *Expropiación petrolera*.

Politics of alternative fuels

Vinod Khosla (a well known investor in IT firms and alternative energy) has argued that the political interests of environmental advocates, agricultural businesses, energy security advocates (such as ex-CIA director James Woolsey) and automakers, are all aligned for the increased production of ethanol. He pointed out that from 2003 to 2006, ethanol fuel in Brazil replaced 40% of its gasoline consumption while flex fuel vehicles went from 3% of car sales to 70%. Brazilian ethanol, which is produced using sugarcane, reduces greenhouse gases by 60-80% (20% for corn-produced ethanol). Khosla also said that ethanol was about 10% cheaper per given distance. There are currently ethanol subsidies in the United States but they are all blender's credits, meaning the oil refineries receive the subsidies rather than the farmers. There are indirect subsidies due to subsidising farmers to produce corn. Vinod says after one of his presentations in Davos, a senior Saudi oil official came up to him and threatened: "If biofuels start to take off, we will drop the price of oil." Since then, Vinod has come up with a new recommendation that oil should be taxed if it drops below $40.00/barrel in order to counter price manipulation.

Ex-CIA director James Woolsey and U.S. Senator Richard Lugar are also vocal proponents of ethanol.

In 2005, Sweden announced plans to end its dependence on fossil fuels by the year 2020.

Geopolitics of oil money

Multibillion-dollar inflows and outflows of petroleum money have worldwide macroeconomic consequences, and major oil exporters can gain substantial influence from their petrodollar recycling activities.

Key oil producing countries

Canada

As development in the Alberta oil sands, deep sea drilling in the North Atlantic and the prospects of arctic oil continue to grow Canada increasingly grows as a global oil exporter. There are currently three major pipelines under proposal that would ship oil

to the pacific, atlantic and gulf ports. These projects have stirred internal controversy, receiving fierce opposition from First Nations groups and environmentalists.

Iran

Discovery of oil in 1908 at Masjed Soleiman in Iran initiated the quest for oil in the Middle East. The Anglo-Iranian Oil Company (AIOC) was founded in 1909. In 1951, Iran nationalized its oil fields initiating the Abadan Crisis. The United States of America and Great Britain thus punished Iran by arranging coup against its democratically elected prime minister, Mosaddeq, and brought the former Shah's son, a dictator, to power. In 1953 the US and GB arranged the arrest of the Prime Minister Mosaddeq. Iran exports oil to China and Russia.

Iraq

Iraq holds the world's second-largest proven oil reserves, with increasing exploration expected to enlarge them beyond 200 billion barrels (3.2×10^{10} m^3) of "high-grade crude, extraordinarily cheap to produce." Organizations such as the Global Policy Forum (GPF) have asserted that Iraq's oil is "the central feature of the political landscape" there, and that as a result of the 2003 invasion,"'friendly' companies expect to gain most of the lucrative oil deals that will be worth hundreds of billions of dollars in profits in the coming decades." According to GPF, U.S. influence over the 2005 Constitution of Iraqhas made sure it "contains language that guarantees a major role for foreign companies."

Mexico

Mexico has a largely oil-based economy, being the seventh largest producer of petroleum. Though Mexico has gradually explored different types of electricity, oil is still crucial, recently generating 10% of revenue.

Before 1938, all petroleum companies in Mexico were foreign based, often from the United States or Europe. The petroleum industry was nationalized in the late 1930s to early 1940s by then-president Lázaro Cárdenas, creating PEMEX. Mexico's oil industry still remains heavily nationalized. Though oil production has fallen in recent years, Mexico still remains in seventh place.

Nigeria

Petroleum in Nigeria was discovered in 1955 at Oloibiri in the Niger Delta.

High oil prices were the driving force behind Nigeria's economic growth in 2005. The country's real gross domestic product (GDP) grew approximately 4.5 percent in 2005 and was expected to grow by 6.2 percent in 2006. The Nigerian economy is heavily dependent on the oil sector, which accounts for 95 percent of government revenues. Even with the substantial oil wealth, Nigeria ranks as one of the poorest countries in the world, with a $1,000 per capita income and more than 70 percent of the population living in poverty. In October 2005, the 15-member Paris Club announced that it would cancel 60 percent of the debt owed by Nigeria. However, Nigeria must still pay $12.4 billion in arrears amongst meeting other conditions. In March 2006, phase two of the Paris Club agreement will include an additional 34 percent debt cancellation, while Nigeria will be responsible for paying back any remaining eligible debts to the lending nations. The International Monetary Fund (IMF), which recently praised the Nigerian government for adopting tighter fiscal policies, will be allowed to monitor Nigeria without having to disburse loans to the country.

Russia

High-priced oil allowed the USSR to subsidize the struggling economies of the Soviet bloc for a time, and the loss of petrodollar income during the 1980s oil glut contributed to the bloc's collapse in 1989.

Saudi Arabia

Saudi Arabia is an oil-based economy with strong government controls over major economic activities. It possesses both the world's largest known oil reserves, which are 25% of the world's proven reserves, and produces the largest amount of the

world's oil. As of 2005, Ghawar field accounts for about half of Saudi Arabia's total oil production capacity.

Saudi Arabia ranks as the largest exporter of petroleum, and plays a leading role in OPEC, its decisions to raise or cut production almost immediately impact world oil prices. It is perhaps the best example of a contemporary energy superpower, in terms of having power and influence on the global stage (due to its energy reserves and production of not just oil, but natural gas as well). Saudi Arabia is often referred to as the world's only "oil superpower".

United States

In 1998, about 40% of the energy consumed by the United States came from oil. The United States is responsible for 25% of the world's oil consumption, while having only 3% of the world's proven oil reserves and less than 5% of the world's population. In January 1980, President Jimmy Carter explicitly declared: "An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States."

Venezuela

According to the Oil and Gas Journal (OGJ), Venezuela has 77.2 billion barrels (1.227×10^{10} m^3) of proven conventional oil reserves, the largest of any country in the Western Hemisphere. In addition it has non-conventional oil deposits similar in size to Canada's - at 1,200 billion barrels (1.9×10^{11} m^3) approximately equal to the world's reserves of conventional oil. About 267 billion barrels (4.24×10^{10} m^3) of this may be producible at current prices using current technology. Venezuela's Orinoco tar sands are less viscous than Canada's Athabasca oil sands – meaning they can be produced by more conventional means, but are buried deeper – meaning they cannot be extracted by surface mining. In an attempt to have these *extra heavy* oil reserves recognized by the international community, Venezuela has moved to add them to its conventional reserves to give nearly 350 billion barrels (5.6×10^{10} m^3) of total oil reserves. This would give it the largest oil reserves in the world, even ahead of Saudi Arabia.

Venezuela nationalized its oil industry in 1975–1976, creating Petróleos de Venezuela S.A. (PdVSA), the country's state-run oil and natural gas company. Along with being Venezuela's largest employer, PdVSA accounts for about one-third of the country’s

GDP, 50 percent of the government's revenue and 80 percent of Venezuela's exports earnings. In recent years, under the influence of President Chavez, the Venezuelan government has reduced PdVSA's previous autonomy and amended the rules regulating the country's hydrocarbons sector.

In the 1990s, Venezuela opened its upstream oil sector to private investment. This collection of policies, called apertura, facilitated the creation of 32 operating service agreements (OSA) with 22 separate foreign oil companies, including international oil majors like Chevron, BP, Total, and Repsol-YPF. Hugo Chávez, the President of Venezuela sharply diverged from previous administrations' economic policies. PDVSA is now used as a cash-cow and as an employer-of-last-resort; foreign oil businesses were nationalised and the government refused to pay compensation.

Estimates of Venezuelan oil production vary. Venezuela claims its oil production is over 3 million barrels per day (480,000 m^3/d), but oil industry analysts and the U.S. Energy Information Administration believe it to be much lower. In addition to other reporting irregularities , much of its production is extra-heavy oil, which may or may not be included with conventional oil in the various production estimates. The U.S. Energy Information Agency estimated Venezuela's oil production in December 2006 was only 2.5 million barrels per day (400,000 m^3/d), a 24% decline from its peak of 3.3 million in 1997.

Recently, Venezuela has pushed the creation of regional oil initiatives for the Caribbean (Petrocaribe), the Andean region (Petroandino), and South America (Petrosur), and Latin America (Petroamerica). The initiatives include assistance for oil developments, investments in refining capacity, and preferential oil pricing. The most developed of these three is the Petrocaribe initiative, with 13 nations signing a preliminary agreement in 2005. Under Petrocaribe, Venezuela will offer crude oil and petroleum products to Caribbean nations under preferential terms and prices, with Jamaica as the first nation to sign on in August 2005.

Project Independence

Project Independence was an initiative announced by U.S. President Richard Nixon on November 7, 1973, in reaction to the OAPEC oil embargo and the resulting 1973 oil crisis. Recalling the Manhattan Project, he stated that the goal of Project Independence was to achieve energy self-sufficiency for the United States by 1980, through a national commitment to energy conservation and development of alternative sources of energy. Nixon declared that American science, technology and industry could free America from its dependence on imported oil, and establish its energy independence. He called for the construction of 1,000 nuclear power plants by the year 2000.

Some of the important initiatives to emerge from Project Independence included lowering highway speeds to 55 mph (89 km/h), converting oil power plants to coal, completion of the Trans-Alaska Pipeline System and diverting federal funds from highway construction to mass transit.

Despite these initiatives, Project Independence failed to prevent the increase in American oil consumption after the 1973-74 embargo; its dependence on foreign suppliers rose from 36% to almost 50% in 1979, when questions of nuclear energy safety arose domestically, and the next energy crisis emerged overseas.

Current Trends and Issues in the Global Oil Markets

To help set the scene for U.S. onshore production, three questions were addressed:

- What is the state of play in global oil markets?
- What is the status of U.S. onshore production?
- What role does U.S. onshore production play in the market?

The average forecast among Organization of Petroleum Exporting Countries (OPEC), Energy Information Administration (EIA), and International Energy Agency (IEA) data puts world GDP (PPP) growth at 3.4 percent in 2017 and 3.7 percent in 2018. With this, growth in oil demand is forecast to be somewhere between 1.3 and 1.5 million barrels per day (mb/d) in 2017.

At the same time, the three organizations estimate a range of 0.4–1.0 mb/d in global supply growth. The EIA, at the high end of the range at 1.0 mb/d in 2017, shows supply and demand rebalancing in Q3 of 2017. Even with global oil supply stocks at a level significantly higher than historical averages, the stronger oil market fundamentals imply higher price forecasts. For example, the EIA forecasts that the price of West Texas Intermediate (WTI) will average $54 in 2017 and $56 in 2018. A variety of factors, some outlined below, could influence the pace of the rebalance throughout the course of this year into next.

U.S. tight oil production remained relatively resilient in the face of low oil prices due to a variety of factors such as leasing and drilling terms, high grading, declining cost of inputs, and productivity improvements. Moreover, even when tight oil production started to decline,

U.S. overall production numbers during this period were bolstered by the onset of offshore oil projects coming online—these factors served to mute the expected decline. While the level of resiliency proved stronger than originally expected, oil production was ultimately affected by lower prices, declining by 0.284 mb/d in 2016 from 2015 output levels. With the recent upturn in prices, an average of 0.16 mb/d has been added in Q1 of 2017 from production levels in Q4 of 2016, showcasing a high level of price responsiveness. The downside facing the market in the short term is that there is still a large amount of stock to work through globally—a process that OPEC producers, along with Russia and several other countries, recently sought to expedite by agreeing to cut 1.8 mb/d of production over the first six months of 2017. The key question is whether U.S. production will simply increase because of higher prices and in the process, dampen a global drawdown in stocks and slow down the global rebalance. OPEC production cuts have been successful so far in reducing levels of stocks globally and have bolstered prices; however, the market has yet to reach a balance between supply and consumption.

While compliance rates have been far from uniform among OPEC producers and public comments made by Russia's minister of energy, Alexander Novak, led to doubts about Russia's commitment to the agreement, the level of cooperation as represented by the most recent production figures appears to be improving. Regardless, to attain the goal of rebalancing the market OPEC must, at minimum, extend the current production agreement into the second half of 2017, otherwise stocks will continue to overhang and prices will remain vulnerable to negative news flow.

A core criticism levied by OPEC at U.S. tight oil producers and investors is that this immediate production response to higher prices is a form of "irrational exuberance," where the firms and investors take short-term cash flow at the expense of longer-term profitability (i.e., if you increase production in response to higher prices, you increase near-term revenue but depress prices again). It appears that as operators drill out more densely to take advantage of short-term production gains, this may be coming at the expense of longer-term productivity across U.S. basins. Over the longer run, this could affect the pace and productivity of certain U.S. tight oil developments.

As the market trends toward balance, supply disruptions and eroding production capacity could expedite the market rebalance and add upward price pressure. Various geopolitical issues to watch out for include the ongoing civil war in Libya, unrest in Nigeria, and the possibility of social unrest in Venezuela leading to collapse. However, for the most part the risks in the short term lie on the side of possible oversupply in the market forcing prices downwards.

n the medium term, there is the possibility of several risks going in the other direction with a possible price shock due to current levels of underinvestment in conventional sources globally.

Conventional crude oil accounts for 75 mb/d of global oil supply and upstream investment in these sources has been drastically cut over the past two years. Conventional oil assets likely

require a sustained price level above $50–$55 a barrel to encourage investment again. The combination of the above, and the fact that demand is expected to grow by 1.3–1.5 mb/d a year, makes a supply gap and a price shock in the medium term a realistic possibility, a gap that depending upon its severity could be met by short-cycle tight oil. The critical issues in examining the potential supply gap are demand estimates, existing production decline rates, and cost and timing consideration of bringing on new incremental projects.

The United States as a Global Oil Supplier

U.S. tight oil production is responding well to the recent oil price rise. Significant increases in drilling and start-up activity in the first quarter of 2017 have been recorded, leading to upward revisions of U.S. oil production outlook. In fact, it is now forecast that U.S. production will increase by approximately 0.4 mb/d between the second and fourth quarters of 2017. This could increase even further if prices climb again. As such, U.S. shale production is a source of price resistance in the market. Whether and how U.S. tight oil production will continue to play this role in the market is dependent upon several other factors, namely the overall supply-and-demand balance in the market, access to capital, drilling economics and infrastructure bottlenecks, and the evolving role of storage.

Today, the five largest shale plays in the United States—the Permian Midland, Permian Delaware, Eagle Ford, Bakken and Niobrara—make up 80 percent of shale production. Base decline rates have significantly fallen across these plays due to productivity gains and cost reductions from service providers, which has driven down wellhead prices. The Permian operators have enjoyed the largest decrease in costs and it is forecast that the Permian will account for 60 percent of growth of shale production in the United States until 2020. While operators in the big five plays are now facing an inflationary environment in 2017, WTI prices above the $55 mark should be enough for shale growth to thrive for many operators in these regions but it will not be enough for growth in other areas. So, beyond the five big plays, there does not appear to be that much potential for additional growth in the near to medium term if prices remain in the $55–$60 range.

Upstream investment for conventional sources among OPEC member states and around the world has seen little activity over the past two years due to the price collapse. However, as recent global inventory levels have been rebalancing thanks to the OPEC supply cuts and if OPEC continues to manage supply and extends these cuts further into 2017, then we will likely see prices go back to the $60 range. Until we see this happen, conventional upstream investment levels will remain suppressed.

In the immediate aftermath of the OPEC-led supply cuts, shale has displayed that it can respond on the margin due to its high level of price elasticity. Shale drilling activity takes

only three months to respond to market price signals. So, the recent dip in WTI below $50 should not immediately affect activity but if WTI is sustained at a level below $50 over the longer run it will negatively affect tight oil production gains in the United States.

At the same time, global demand for oil will continue to grow for the foreseeable future. For example, the International Monetary Fund (IMF) still forecasts that the Chinese economy will grow by 6.5 percent this year, and while there is potential for this to be revised downwards given the levels of growing debt, this estimate nonetheless suggests that China will still account for large levels of growth in demand. Furthermore, OECD demand for oil is also up due to gains in transportation and industrial output. These factors of continued growth in demand and reduced levels of investment may result in the formation of a supply gap in the market in the medium term. With this potential supply hole coming down the road, U.S. shale will likely smooth the price spikes in the market and may potentially continue to provide a price ceiling, due to the superior price responsiveness of U.S. shale as exhibited by the gains made in the first quarter of 2017. However, the extent to which U.S. tight oil will provide a price ceiling will of course depend on the size and severity of any supply shortfall, as well as the outcomes of existing field decline rates and cost compression in future upstream projects.

In a short period of time, the United States has transformed from being the world's largest importer of refined petroleum products to the largest exporter with potentially important strategic implications. Growth of refining capacity has been robust as of recent, with 1.7 mb/d of capacity added between 2012 and 2017. One factor in recent growth has been the decline seen in Venezuelan refining capacity, alongside an increase in product demand globally.

The U.S. downstream will face challenges. Competition is increasing with refineries being developed in product-importing countries like India and in several Southeast Asian nations, many of which are collaborating with the Middle East and Russia. Furthermore, refining capacity has stagnated on the U.S. west coast due to poor margins; however, 50 percent of U.S. refining capacity is now located on the Gulf Coast where margins are better. New environmental regulations affect refinery performance but the prospect for increased regulation within the United States has lessened relative to expectations before the 2016 elections.

Regardless of the above challenges, refineries in the United States are massive by volume and remain technically superior in comparison to overseas competition. For example, U.S. refiners are better able to cope with international regulations to improve environmental performance, like the International Maritime Organization (IMO) sulfur standards, relative to many other refineries since they remain at the cutting edge in terms of capabilities and are therefore able to adapt more easily. Moreover, the ability to take a wide variety of crudes and turn them into products gives the United States an added advantage in global oil markets because they can compete equally well in global refined product markets or crude markets as the prices dictate.

Key Strategic Issues in Policy Choices

The United States has abundant natural resources, world-class innovators, and a robust private sector-led approach to energy development. For decades, U.S. energy policy has sought to provide affordable reliable energy supplies to a growing and prospering population while also improving environmental performance and lessening imports of energy in the name of greater energy security. With the slowdown in U.S. economic growth, greater efficiency, the improved development of a variety of energy resources (including tight oil), and the growing imperative to reduce emissions to deal with climate change, U.S. energy policy and regulation underwent some remarkable changes. Both federal and local rules were changed to accommodate a shifting market and technological environment but also to drive particular outcomes in the energy sector. With the election of a new administration with different energy priorities from the previous administration, the question of how U.S. policy might affect tight oil production and consumption and in turn influence global oil markets is increasingly relevant.

The following categories may be useful to assess how the United States may shape its evolving role in global oil markets given the policy priorities advanced by the new administration:

- Tax and revenue
- Environmental regulation reforms
- Trade
- Energy Independence

One of the top priorities of the new administration is that of tax reform, which will likely be a deeply contentious issue. Historically tax reform has required a great deal of political capital to achieve and since the Trump administration has many proposed policy priorities on the table, others will likely have to be sacrificed to get tax reform through. Tax reform does, however, happen to be a major priority for the Republican-controlled Congress as well.

The provision of proposed tax reforms that has drawn most attention is the destination-based border adjusted corporate tax (BAT). The essential elements of the BAT include a lowering

of the corporate tax rate from 35 percent to 20 percent; immediate expensing of investments; taxation in the United States only; no tax on exports; and a 20 percent tax on imported goods and services (the so-called border adjustment). The BAT is often labeled as a trade policy, but it is more appropriately referenced as a tax policy with trade effects. The goal of the BAT is to eliminate incentives to locate business operations outside of the United States by essentially taxing imported goods and providing for a tax break on exported goods. Sponsors claim that the appreciation of the dollar, which they expect to rise by 25 percent because of this policy, will offset the 20 percent tax that importers will pay.

The presumed appreciation of the dollar raises questions about all dollar-denominated trade. The appreciation of the dollar could send prices of dollar-denominated commodities, such as oil, down. However, this proposed change in corporate tax policy faces stiff opposition from major importers (retailers, industrial companies, and coastal refiners) that are concerned about the level of tax and skeptical of the timing and extent of U.S. dollar appreciation.

Both in its campaign platform and through a series of executive orders during its first hundred days, the administration has sought to roll back a series of policy measures and regulations set forth by the Obama administration. These include changes to federal policies in federal land leasing; the Clean Power Plan (CPP); Corporate Average Fuel Economy (CAFE) standards; methane emissions; and the Clean Water Act (CWA). The majority of the proposed environmental regulatory amendments would affect the supply side of the market. For example, the proposed rollback of methane emission limits on new wells and removal of limits imposed on existing wells along with the proposed modification or revocation of the Waters of the United States (WOTUS) rule will reduce compliance costs for the industry and streamline the permitting process.

However, there is uncertainty surrounding how President Trump will accomplish his “deregulatory” agenda using executive orders. Legally, executive orders do not automatically change an agency’s administrative rule. For this to occur it would require a new rule from the

agency changing the old regulation, which can be subject to litigation for violating the agency's statutory mandate. More importantly, these processes are time consuming even absent litigation. This causes some uncertainty as to how quickly these changes will happen. Furthermore, many agencies require people in positions who can oversee the process for modification of existing regulations. Many key positions remain unfilled in the administration, which will make moving these changes forward difficult. There is also uncertainty around how successful the goal of permit streamlining will be. While Trump can ease the burden at the federal level it may not make much of an impact because there is a lot of opposition that can come from the state and local level.

Finally, the bigger risk for the industry is that of a pendulum effect. Could the strong anti-regulatory agenda by this administration produce a tough backlash regulatory agenda in a future administration? This is a risk that many in industry have come to expect and requires risk management for investments spanning administrations.

NAFTA, which dates to the early 1990s, appears to be another primary focus for the new administration. While there is scope to strengthen NAFTA in the United States' favor, the biggest threat of a NAFTA renegotiation is the disruption of supply chains and a change to the rules of origins requirements. The negotiations over country-of-origin content requirements in NAFTA could be the most contentious negotiating point.

The last nine administrations have tried hard to improve relations with Mexico where it has traditionally been politically pragmatic to be seen standing up to the United States. Any renegotiation increases the threats of increased political tensions and cross-border tariff retaliation. The energy trade situation with Mexico has changed significantly in recent years. In 2015 and 2016, the value of U.S. energy exports to Mexico exceeded the value of U.S. energy imports from Mexico. About 60 percent of U.S. gas exports go to Mexico and this would be detrimentally impacted by any changes to NAFTA.

Once again the border adjustment tax, while it is not necessarily a trade policy, if implemented would have trade implications. Under World Trade Organization rules, the tax break given to exported goods may be interpreted as an explicit export subsidy and so the United States will likely face backlash from the European Union or other major trading

partners. Also, the appreciation of the dollar that would come with such a policy would increase all deficits, thus making the goal of renegotiating NAFTA to help reduce the deficit with Mexico more difficult to achieve.

A longstanding focus of U.S. energy policy has been the quest for “energy independence.” Often accused of being more slogan than a substantive goal, the notion of energy independence was born out of the scarcity in oil supply arising as a result of the oil embargoes of the 1970s. The notion that energy self-sufficiency would free the United States from the insecurity of oil import dependence, the foreign policy leverage and interlinkages with oil exporting regions of the world, and positively impact the trade balance of the United States has been a political driver for much of the policy efforts and strategic posture of U.S. energy policy ever since.

As the United States inches ever closer to energy self-sufficiency, it is worth asking what the overarching priorities of U.S. energy policy might become in the years ahead and whether or not energy independence delivers the strategic advantages it has promised over the last several decades. There are no easy or immediate answers to this, not least of which is because the central tension in U.S. energy policy at the moment hinges on disagreement concerning climate change and not energy independence.

Economy of Saudi Arabia

The **economy of Saudi Arabia** is dependent on oil and has strong government control over major economic activities. The Saudi economy is the largest in the Arab world. Saudi Arabia has the world's second-largest proven petroleum reserves and the country is the largest exporter of petroleum. It has also the fifth-largest proven natural gas reserves. Saudi Arabia is considered an "energy superpower". It has third highest total estimated value of natural resources, valued at US$34.4 trillion in 2016.

Saudi oil reserves are the second largest in the world, and Saudi Arabia is the world's leading oil exporter and second largest producer. Proven reserves, according to figures provided by the Saudi government, are estimated to be 260 billion barrels (41 km^3), about one-quarter of world oil reserves. Petroleum in Saudi Arabia is not only plentiful but under pressure and close to the earth's surface. This makes it far cheaper and thus far more profitable to extract petroleum in Saudi Arabia than in many other places. The petroleum sector accounts for roughly 87% of Saudi budget revenues, 90% of export earnings, and 42% of GDP.

Another 40% of GDP comes from the private sector. An estimated 7.5 (2013) million foreigners work legally in Saudi Arabia, playing a crucial role in the Saudi economy, for example, in the oil and service sectors. The government has encouraged private sector growth for many years to lessen the kingdom's dependence on oil, and to increase employment opportunities for the swelling Saudi population. In recent decades the government has begun to permit private sector and foreign investor participation in sectors such as power generation and telecom, and acceded to the WTO. During much of the 2000s, high oil pricesenabled the government to post budget surpluses, boost spending on job training and education, infrastructure development, and government salaries. More than 95% of all Saudi oil is produced on behalf of the Saudi Government by the parastatal giant Saudi Aramco, and the remaining 5% by similar parastatal companies as of 2002.

With its absolute monarchy system of government, large state sector and supply of welfare benefits, the Saudi economy has been described as

a bewildering (at least to outsiders) combination of a feudal fealty system and a more modern political patronage one. At every level in every sphere of activity, Saudis

maneuver through life manipulating individual privileges, favors, obligations, and connections. By the same token, the government bureaucracy is a maze of overlapping or conflicting power center under the patronage of various royal princes with their own priorities and agendas to pursue and dependents to satisfy.

The gross domestic product of Saudi Arabia fluctuates dramatically according to the price of oil .

Saudi Arabia was a subsistence economy until the 1930s. During the 1973 oil crisis Saudi began to grow rapidly and peaked around 1980. In the mid 1980s the oil price dropped from a high of US$40 per barrel to around US$5, and the country built up a massive overseas debt. From 2002 to mid-2008 oil prices recovered, allowing the government to post budget surpluses, and boost spending.

Saudi Arabia was an economy based on subsistence agriculture by a population that was largely nomadic and very poor until the discovery of oil in the 1930s. To raise the price of oil, Saudi Arabia and several other major exporters (Venezuela, Iraq, Iran and Kuwait) founded the Organisation of the Petroleum Exporting Countries (OPEC), to regulate production. The first five-year "Development Plan" was started in 1970, and these have continued sequentially with 2015 being the first year of the tenth plan.

During the 1973 oil crisis OPEC production cuts raised the price of petroleum from $3 per barrel to nearly $12. Saudi became one of the fastest-growing economies in the world. It enjoyed a substantial surplus in its overall trade with other countries; imports increased rapidly; and ample government revenues were available for development, defense, and aid to other Arab and Islamic countries. Another price jolt around 1980 during the Iran–Iraq War brought Saudi Arabia to what has (so far) been its economic peak (in terms of per capita income).

But higher oil prices led to development of more oil fields around the world and reduced global consumption. The result, beginning in the mid-1980s, was a worldwide oil glut, with the oil price dropping from a high of US$40 per barrel to a low point of around US$5. This introduced an element of planning uncertainty for the first time in a decade. Saudi oil production, which had increased to almost 10 million barrels (1,600,000 m^3) per day during 1980–81, dropped to about 2 million barrels per day (320,000 m^3/d) in 1985. Budgetary deficits developed, and the government drew down its foreign assets.Responding to financial pressures, Saudi Arabia gave up its role as the "swing producer" within OPEC in the summer of 1985 and accepted a production quota. Since then, Saudi oil policy has been guided by a desire to maintain market and quota shares.

In June 1993, Saudi Aramco absorbed the state marketing and refining company (SAMAREC), becoming the world's largest fully integrated oil company. Most Saudi oil exports move by tanker from oil terminals at Ras Tanura and Ju'aymah in the Persian Gulf. The remaining oil exports are transported via the east-west pipeline across the kingdom to the Red Sea port of Yanbu. A major new gas initiative promises to bring significant investment by U.S. and European oil companies to develop non-associated gas fields in three separate parts of Saudi Arabia. Following final technical agreements with concession awardees in December 2001, development should begin in 2002.

However, beginning in late 1997, Saudi Arabia again faced the challenge of low oil prices. Due to a combination of factors—the East Asian economic crises, a warm winter in the West caused by El Niño, and an increase in non-OPEC oil production—demand for oil slowed and pulled oil prices down by more than one-third.

Saudi Arabia was a key player in coordinating the successful 1999 campaign of OPEC and other oil-producing countries to raise the price of oil to its highest level since the Persian Gulf War by managing production and supply of petroleum. That same year, Saudi Arabia established the Supreme Economic Council to formulate and better coordinate economic development policies in order to accelerate institutional and industrial reform.

Saudi Arabia acceded to the WTO in 2005 after many years of negotiations.

Foreign investment

The mid-1980s was also the time that foreign ownership of business was allowed. In the mid-1990s, foreign ownership rules were relaxed again, with investment sought in telecommunications, utilities, and financial services. In 2000, 100% foreign-owned businesses were allowed in the kingdom.

Since 2008, extensive land investment has taken place, especially in Africa .

Diversification and the development plans

The government has sought to allocate its petroleum income to transform its relatively undeveloped, oil-based economy into that of a modern industrial state while maintaining the kingdom's traditional Islamic values and customs. Although economic planners have not achieved all their goals, the economy has progressed rapidly. Oil wealth has increased the standard of living of most Saudis. However, significant population growth has strained the government's ability to finance further improvements in the country's standard of living. Heavy dependence on petroleum

revenue continues, but industry and agriculture now account for a larger share of economic activity. The mismatch between the job skills of Saudi graduates and the needs of the private job market at all levels remains the principal obstacle to economic diversification and development; about 4.6 million non-Saudis are employed in the economy.

Saudi Arabia first began to diversify its economy to reduce dependency on oil in the 1970s as part of its first five-year development plan. Basic petrochemical industries using petroleum byproducts as feedstock were developed. The fishing villages of al-Jubail on the Persian Gulf and Yanbu on the Red Sea were developed. However, their effect on Saudi Arabia's economic fortunes has been small.

Saudi Arabia's first two development plans, covering the 1970s, emphasized infrastructure. The results were impressive—the total length of paved highways tripled, power generation increased by a multiple of 28, and the capacity of the seaports grew tenfold. For the third plan (1980–85), the emphasis changed. Spending on infrastructure declined, but it rose markedly on education, health, and social services. The share for diversifying and expanding productive sectors of the economy (primarily industry) did not rise as planned, but the two industrial cities of Jubail and Yanbu—built around the use of the country's oil and gas to produce steel, petrochemicals, fertilizer, and refined oil products—were largely completed.

In the fourth plan (1985–90), the country's basic infrastructure was viewed as largely complete, but education and training remained areas of concern. Private enterprise was encouraged, and foreign investment in the form of joint ventures with Saudi public and private companies was welcomed. The private sector became more important, rising to 70% of non-oil GDP by 1987. While still concentrated in trade and commerce, private investment increased in industry, agriculture, banking, and construction companies. These private investments were supported by generous government financing and incentive programs. The objective was for the private sector to have 70% to 90% ownership in most joint venture enterprises.

The fifth plan (1990–95) emphasized consolidation of the country's defenses; improved and more efficient government social services; regional development; and, most importantly, creating greater private-sector employment opportunities for Saudis by reducing the number of foreign workers.

The sixth plan (1996–2000) focused on lowering the cost of government services without cutting them and sought to expand educational training programs. The plan called for reducing the kingdom's dependence on the petroleum sector by diversifying economic activity, particularly in the private sector, with special emphasis on industry and agriculture. It also continued the effort to "Saudiize" the labor force.

The seventh plan (2000–2004) focuses more on economic diversification and a greater role of the private sector in the Saudi economy. For 2000–04, the government aims at an average GDP growth rate of 3.16% each year, with projected growths of 5.04% for the private sector and 4.01% for the non-oil sector. The government also has set a target of creating 817,300 new jobs for Saudi nationals.

Advertising expenditures have reached new peaks due to emphasis on value-added manufacturing.

As part of its diversification, Saudi Arabia has been inking major refinery contracts with Chinese and other companies.

Future plans

Saudi Arabia has announced plans to invest about $47 billion in three of the world's largest and most ambitious petrochemical projects. These include the $27 billion Ras Tanura integrated refinery and petrochemical project, the $9 billion Saudi Kayan petrochemical complex at Jubail Industrial City, and the $10 billion Petro Rabigh refinery upgrade project. Together, the three projects will employ more than 150,000 technicians and engineers working around the clock. Upon completion in 2015–16, the Ras Tanura integrated refinery and petrochemicals project will become the world's largest petrochemical facility of its kind with a combined production capacity of 11 million tons per year of different petrochemical and chemical products. The products will include ethylene, propylene, aromatics, polyethylene, ethylene oxide, chlorine derivatives, and glycol.

Saudi Arabia had plans to launch six "economic cities" (e.g. King Abdullah Economic City, to be completed by 2020) in an effort to diversify the economy and provide jobs. They are being built at a cost of $60bn (2013)and are "expected to contribute $150bn to the economy".As of 2013 four cities were being developed.

Employment

As of 2008, roughly two thirds of workers employed in Saudi Arabia were foreigners, and in the private sector approximately 90%. In January 2014, the Saudi government claimed it had lowered the 90% rate, doubling the number of Saudi citizens working in the private sector employment to 1.5 million. (This compares to 10 million foreign expatriates working in the kingdom.)

According to Reuters, economists "estimate only 30–40 percent of working-age Saudis hold jobs or actively seek work," although the official unemployment rate is only around 12 percent. Most Saudis with jobs are employed by the government, but the International Monetary Fund has warned the government cannot support such a large wage bill in the long term. The government has announced a succession of plans since 2000 to deal with the imbalance by "Saudizing" the economy, However, the foreign workforce and unemployment among Saudis has continued to grow.

One obstacle is social resistance to certain types of employment. Jobs in service and sales are considered totally unacceptable for citizens of Saudi Arabia—both potential employees and customers.

Non-petroleum sector

Saudi Arabia has natural resources other than oil, including small mineral deposits of gold, silver, iron, copper, zinc, manganese, tungsten, lead, sulphur, phosphate, soapstone and feldspar. The country has a small agricultural sector, primarily in the southwest where annual rainfall averages 400 mm (16"). The country is one of the world's largest producers of dates. For some years it grew very expensive wheat using desalinated water for irrigation, but plans to stop by 2016. As of 2009, livestock population amounted to 7.4 million sheep, 4.2 million goats, half a million camels and a quarter of a million cattle.

Although jobs created by the roughly two million annual *hajj* pilgrims do not last long, the hajj employs more people than the oil industry—40,000 temporary jobs (butchers, barbers, coach drivers, etc.)—and US$2–3 billion in revenue.

In 2008, the "Initiative for Saudi Agricultural Investment Abroad" was launched, leading to extensive billion-dollar purchases of large tracts of land around the world: Ethiopia, Indonesia, Mali, Senegal, Sudan and others. Critics see cases of land-grabbing in various instances that also lead to uproars in the respective countries. Competing industrialising nations with food security problems in the quest for agricultural land are China, South Korea and India as well as the Persian Gulf States Kuwait, Qatar and the UAE.

Real estate

One of the fastest growing sectors in the country has been real estate, although this is yet to achieve its full potential despite some shortages in both residential and commercial real estate. A number of regional experts believe that most issues will be resolved as the market becomes more mature.

Real estate plays a fundamental role in the country's non-oil economy. In 2016, the value of real estate transactions including sales of existing units amounted to SR 281 billion from October 15 to September 16. It should be noted that is a major drop compared to the number of transactions recorded a decade earlier, which reached SR 900 billion. The real estate sector has been driven recently by strong local demand fundamentals and only a small amount by speculation.

Ownership of land in Saudi Arabia is generally restricted to Saudis, but this is subject to certain qualifications. For example, Gulf Cooperation Council ('GCC') nationals and GCC companies have certain rights to own land, subject to a number of restrictions.

The major expansion in this sector attracted the top real estate consultancies such as Jones Lang LaSalle , Knight Frank and Cluttons to the country who have now opened offices in the country. Beyond this, demand for professional real estate services is attracting regional educators such as DREI to provide courses on Saudi real estate, and even dedicated books focused on the market such as Saudi Real Estate Companion.

Real Estate plays an important role in the Kingdom's 2030 vision which maps out significant commitments by the Saudi Government relating to housing and the development of land for a variety of uses. In particular, Vision 2030 states: 'Where it exists in strategic locations, we will also capitalise on the government's reserves of real estate. We will allocate prime areas within cities for educational institutions, retail, and entertainment centres, large areas along our coasts will be dedicated to tourist projects and appropriate lands will be allocated for industrial projects.'

Under the National Transformation Plan (the 'Plan'), the housing sector, with a budget of SAR 59 billion, is the biggest area of government expenditure. The Plan also has targets of:

- increasing real estate sector contribution from GDP five per cent to 10 per cent;

- establishing partnerships with private sector developers to develop government land for housing projects;
- establishing fast-track licenses and special finance packages to encourage private sector investment in housing projects.

Private sector

Saudi Arabia's private sector is dominated by a handful of big businesses in the service sector, primarily in construction and real estate— Olayan, Zamil, Almarai, Mobily, STC, SABIC, Sadara, Halliburton, Baker Hughes, Flynas, Hilton, Zain, Yanbu Cement, Alhokair, MBC, Mahfouz, and Al Rajhi. These firms are "heavily dependent on government spending", which is dependent on oil revenues.

From 2003–2013, "several key services" were privatized—municipal water supply, electricity, telecommunications—and parts of education and health care, traffic control and car accident reporting were also privatized. According to Arab News columnist Abdel Aziz Aluwaisheg, "in almost every one of these areas, consumers have raised serious concerns about the performance of these privatized entities."

Trade

In recent years, Saudi Arabia sought to join the World Trade Organization. Negotiations have focused on the degree to which Saudi Arabia is willing to increase market access to foreign goods and services and the timeframe for becoming fully compliant with World Trade Organization obligations. In April 2000, the government established the Saudi Arabian General Investment Authority to encourage foreign direct investment in Saudi Arabia. Saudi Arabia maintains a negative list of sectors in which foreign investment is prohibited, but the government plans to open some closed sectors such as telecommunications, insurance, and power transmission/distribution over time. As of November 2005, Saudi Arabia was officially approved to enter World Trade Organization. Saudi Arabia became a full WTO Member on 11 December 2005.

List of trade organizations

World Trade Organization (WTO)

- International Monetary Fund (IMF)

- International Chamber of Commerce (ICC)
- International Organization for Standardization (IOS)
- World Customs Organization (WCO)
- Gulf Cooperation Council (GCC)

Challenges

Among the challenges to Saudi economy include halting or reversing the decline in per capita income, improving education to prepare youth for the workforce and providing them with employment, diversifying the economy, stimulating the private sector and housing construction, diminishing corruption and inequality. In answer to the question of why the Saudi economy is so dependent on foreign labor, the UN Arab Human Development Report blamed stunted social and economic development inhibited by lack of personal freedom, poor education and government hiring based on factors other than merit, and exclusion of women.

Income drop

Despite possessing the largest petroleum reserves in the world, per capita income dropped from approximately $18,000 at the height of the oil boom (1981) to $7,000 in 2001, according to one estimate. As of 2013, per capita income in Saudi was "a fraction of that of smaller Persian gulf neighbors", even less than petroleum-poor Bahrain.

Unlike most developed countries where gross domestic product growth is a function of increases in productivity and inputs such as employment, in Saudi the fluctuation of oil prices is the most important factor in the growth or decline of domestic production. "Saudi reserves are steadily being depleted, and no significant new discoveries have been found to replace them," according to Middle East journalist Karen House. Saudi population grew sevenfold from 1960 to 2010, and petrol prices are subsidized and cost users less than equivalent quantities of bottled water. With production stagnant, growth in population and domestic energy consumption means a decline in per capita income unless oil prices rise to match that growth.

Demographics

Saudi population is young. About 51% are under the age of 25 (as of Feb 2012). According to a 2013 report by the International Monetary Fund, up to 1.6 million young nationals of the Persian gulf countries (of which Saudi Arabia is the largest)

will enter the workforce from 2013 to 2018, but the economies of those countries will have jobs in the private sector for less than half (approximately 600,000).

Education

According to ***The Economist magazine***, the Saudi government has attempted in years past to raise employment by forcing "companies to fill at least 30% of their positions" with Saudi citizens. However, "employers complained bitterly about the lack of skills among young locals; years of rote-learning and religious instruction fail to prepare them for the job market." As a consequence, "the quota has now been dropped and replaced with a more flexible system."

According to another source (scholar David Commins), the kingdom depends "on huge numbers of expatriates workers to fill technical and administrative positions" in part because of an educational system that in spite of "generous budgets", has suffered from "poorly trained teachers, low retention rates, lack of rigorous standards, weak scientific and technical instruction and excessive attention to religious subjects".

Another statistic conducted by Bayt.com shows that over a quarter (28%) of professionals believe that there is a skills shortage in their country of residence. This belief is more prominent among respondents in Saudi Arabia (39%).

Innovation

Saudi has not been a hotbed of technological innovation. The number of Saudi patents registered in the United States between 1977 and 2010 came to 382—less than twelve per year—compared to 84,840 patents for South Korea or 20,620 for Israel during that period. Saudi hopes to increase technological innovation, particularly with the King Abdullah University of Science and Technology, and thus to stimulate the economy.

Legal system

Saudi Arabia's legal system is based on Shariah (Islamic law), which comes from interpretations from the Quran and the Sunnah.

The author of a book on the Saudi legal system (Frank Vogel) bemoaned the

"unpredictability of decisions; obscure if not occult doctrine; dissonance between many Saudi commercial norms and those prevailing nearly everywhere else ... huge costs on the Saudi economy. That the king and government have not been inclined, or

able, to impose a solution to this widely known difficulty is an apt measure of the cultural and political influence of fiqh and ulama and of the centrality of the shari'a ideal for Saudi life public and private."

Bureaucracy

A business journalist (Karen House) criticizing the Saudi bureaucracy complained that someone seeking to start a business in Saudi Arabia

has to complete innumerable applications and documents at multiple layers of multiple ministries, which invariably requires seeking favors from various patronage networks and accumulating obligations along the way, most probably including having to hire less-than-competent dependents of his patrons. Then, for any business of any size, government contracts, not private competition, are the financial lifeblood. So this means more patrons, more favors, and more obligations. Not surprisingly, Saudi businesses that can compete outside the protected Saudi market are few.

Corruption

The cost of maintaining the Royal Family is estimated by some to be about US$10 billion per year. A 2005 survey by the Riyadh Chamber of Commerce found 77% of businessmen polled felt they had to `bypass` the law to conduct their operations. Since then "businessmen say it has only gotten worse."

Poverty

Estimates of the number of Saudis below the poverty line range from between 12.7% and 25%.Press reports and private estimates as of 2013 "suggest that between 2 million and 4 million" of the country's native Saudis live on "less than about $530 a month" – about $17 a day – considered the poverty line in Saudi Arabia. In contrast, Forbes magazine estimates King Abdullah's personal fortune at $18 billion.

The Saudi state discourages calling attention to or complaining about poverty. In December 2011, days after the Arab Spring uprisings, the Saudi interior ministry detained reporter Feros Boqna and two colleagues (Hussam al-Drewesh and Khaled al-Rasheed) and held them for almost two weeks for questioning after they uploaded a 10-minute video on the topic (*Mal3ob 3alena*, or 'We are being cheated') to YouTube. Authors of the video claim that 22% of Saudis are considered to be poor (2009) and 70% of Saudis do not own their houses. Statistics on the issue are not available through the UN resources because the Saudi government does not issue poverty figures. Observers researching the issue prefer to stay anonymous because of the risk of being arrested, like Feras Boqna.

Housing

Only 30% of Saudi Arabia's citizens own their own home, compared to the international average rate of 70% ownership. In 2011, analysts estimated 500,000 new homes/year were needed to match the growth in Saudi population, but as of early 2014 only 300,000 to 400,000 houses/year were being built.

One problem is that the government Real Estate Development Fund (REDF)—which provides 81% of all loans for housing—had a 18-year waiting list for loans due to pent-up demand. Another is that the REDF's maximum loan is 500,000 SR ($133,000), while in 2012 the average price for a small free-standing home in Riyadh is more than double that—1.23 million SR ($328,000).

A major reason for the high cost of housing is the high cost of land. In urban areas the price of land has been bid up because nearly all of it is owned by the Saudi elite (members of the royal family or other wealthy Saudis), who have lobbied the government for land "giveaways". Landlords have seen prices rocket by 50% from 2011 to 2013. The owners benefit from these price increases as they hold the land for future development. To deal with the key "land banking" issue the Housing Minister suggested in 2013 that landowners of vacant within city limits could be subject to a tax. However, no firm plans for any tax have been unveiled.

Further diversification

According to journalist Karen House, "every" Saudi five-year plan "since the first one in 1970" has called for diversifying the economy beyond oil, but with marginal success.

As of 2007, manufacturing outside of the petroleum industry contributed 10% to Saudi Arabian GDP and less than 6% of total employment.

Investment

Saudi Arabia has one stock exchange, the Tadawul, whose financial markets are regulated by the Capital Market Authority. The stock market capitalisation of listed companies in Saudi Arabia was valued at $646 billion in 2005 by the World Bank.

Doing business

The Kingdom of Saudi Arabia has been rated as the 92nd for ease of doing business, according to the World Bank in its annual "Doing Business" report issued for 2018. Since 2013, the Kingdom has declined in the overall Doing Business rankings, from 22nd to 92nd.

Saudi Arabian companies dominate 2009's "MEED 100", with companies listed on the Tadawul, accounting for 29 out of the region’s 100 biggest publicly quoted companies ranked by market capitalisation. Just three of the 20 companies that have dropped out of the top 100 over the past year are listed on the Saudi stock exchange.

Foreigners are allowed to wholly own limited liability companies in the majority of industries. Non-Saudi nationals are required to obtain a foreign capital investment license from the Saudi Arabian General Investment Authority (SAGIA).

Companies

Saudi ARAMCO

Saudi Aramco (officially the Saudi Arabian Oil Co.), is a Saudi Arabian national petroleum and natural gas company based in Dhahran, Saudi Arabia. Saudi Aramco's value has been estimated at up to US$10 trillion in the *Financial Times*, making it the world's most valuable company. (ARAMCO is state-owned and unlisted.)

Saudi Aramco has both the largest proven crude oil reserves, which it claims to be more than 260 billion barrels (4.1×10^{10} m^3), and largest daily oil production. Headquartered in Dhahran, Saudi Arabia, Saudi Aramco operates the world's largest single hydrocarbon network, the Master Gas System. Its yearly production is 3.479 billion barrels (553,100,000 m^3), and it managed over 100 oil and gas fields in Saudi Arabia, including 284.8 trillion standard cubic feet (scf) of natural gas reserves. Saudi Aramco owns the Ghawar Field, the world's largest oil field, and the Shaybah Field, another one of the world's largest oil fields.

SABIC

The Saudi Arabian Basic Industries Corporation SABIC was established by a royal decree in 1976 to produce chemicals, polymers, and fertilizers. In 2008, SABIC was Asia's largest (in terms of market capitalization) and most profitable publicly listed non-oil company, the world's fourth-largest petrochemical company, ranked 186th as world's largest corporation on the Fortune Global 500 for 2009, the second largest producer of ethylene glycol and methanol in the world, the third largest producer of polyethylene and overall the fourth-largest producer of polypropylene and polyolefin. Standard & Poor's and Fitch Ratings claimed SABIC to be the world's largest producer of polymers and the Persian gulf region's largest steel producer for 2005 and assigned SABIC an "A" corporate credit rating. In 2008, Fortune 500 ranking records SABIC revenues at $40.2 billion, profits at $5.8 billion and assets standing at $72.4 billion.

Ma'aden (company)

Ma'aden was formed as a Saudi joint stock company on 23 March 1997 for the purpose of facilitating the development of Saudi Arabia’s mineral resources. Ma'aden's activities have focused on its active goldbusiness which has grown in recent years to include the operation of five gold mines: Mahd Ad Dahab, Al Hajar, Sukhaybarat, Bulghah, and Al Amar. Ma'aden is now expanding its activities beyond its gold business with the development of phosphates, aluminum, and other projects. In addition, since its formation, Ma'aden (through the Ministry of Petroleum and Mineral Resources) has collaborated with the government and local legislators to develop a regulatory framework for the governance of the mining industry.

ICT Services

Saudi Arabia is currently enjoying a massive boom in its personal computer industry since the deregulation of 2002. PC per capita has exploded to nearly 43% of the population in 2005 from just 13% in 2002 leapfrogging over the rest of West Asia. The electrical and electronic market was estimated to be around $3.5 billion in 2004.

The Saudi ICT sector has grown significantly over the last decade and is still showing strong growth. In 2012, ICT sector spending was recorded at SAR 94 billion, with 13.9% annual growth, and reached approximately SAR 102 billion in 2013, with approximately 14% annual growth.

The e-commerce market was estimated at just over $1 billion in 2001.

Coal

Coal is a combustible black or brownish-black sedimentary rock usually occurring in rock strata in layers or veins called **coal beds** or **coal seams**. The harder forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. Coal is composed primarily of carbon, along with variable quantities of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen. Coal is a fossil fuel that forms when dead plant matter is converted into peat, which in turn is converted into lignite, then sub-bituminous coal, after that bituminous coal, and lastly anthracite. This involves biological and geological processes. The geological processes take place over millions of years.

Throughout human history, coal has been used as an energy resource, primarily burned for the production of electricity and heat, and is also used for industrial purposes, such as refining metals. Coal is the largest source of energy for the generation of electricity worldwide, as well as one of the largest worldwide anthropogenic sources of carbon dioxide releases. The extraction of coal, its use in energy production and its byproducts are all associated with environmental and health effects including climate change.

Coal is extracted from the ground by coal mining. Since 1983, the world's top coal producer has been China. In 2015 China produced 3,747 million tonnes of coal – 48% of 7,861 million tonnes world coal production. In 2015 other large producers were United States (813 million tonnes), India (678), European Union (539) and Australia (503). In 2010 the largest exporters were Australia with 328 million tonnes (27% of world coal export) and Indonesia with 316 million tonnes (26%), while the largest importers were Japan with 207 million tonnes (18% of world coal import), China with 195 million tonnes (17%) and South Korea with 126 million tonnes (11%).

Coal as fuel

Further information: Electricity generation, Clean coal technology, Global warming, and List of coal power stations

Coal is primarily used as a solid fuel to produce electricity and heat through combustion. According to the EIA, world coal consumption is projected to increase

from 2012 to 2040 at an average rate of 0.6%/year, from 153 quadrillion Btu (1 Quad are 36,000,000 tonnes of coal) in 2012 to 169 quadrillion Btu in 2020, and to 180 quadrillion Btu in 2040. Efforts around the world to reduce the use of coal has led some regions to switch to natural gas.

China produced 3.47 billion tonnes (3.83 billion short tons) in 2011. India produced about 578 million tonnes (637.1 million short tons) in 2011. 69% of China's electricity comes from coal. The US consumed about 13% of the world total in 2010, i.e. 951 million tonnes (1.05 billion short tons), using 93% of it for generation of electricity. 46% of total power generated in the US was using coal. The United States Energy Information Administration estimates coal reserves at 948×10^9 short tons (860 Gt). One estimate for resources is 18,000 Gt.

When coal is used for electricity generation, it is usually pulverized and then burned in a furnace with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. The thermodynamic efficiency of this process has been improved over time; some older coal-fired power stations have thermal efficiencies in the vicinity of 25%whereas the newest supercritical and "ultra-supercritical" steam cycle turbines, operating at temperatures over 600 °C and pressures over 27 MPa (over 3900 psi), can achieve thermal efficiencies in excess of 45% (LHV basis) using anthracite fuel, or around 43% (LHV basis) even when using lower-grade lignite fuel. Further thermal efficiency improvements are also achievable by improved pre-drying (especially relevant with high-moisture fuel such as lignite or biomass) and cooling technologies.

An alternative approach of using coal for electricity generation with improved efficiency is the integrated gasification combined cycle (IGCC) power plant. Instead of pulverizing the coal and burning it directly as fuel in the steam-generating boiler, the coal is gasified to create syngas, which is burned in a gas turbine to produce electricity (just like natural gas is burned in a turbine). Hot exhaust gases from the turbine are used to raise steam in a heat recovery steam generator which powers a supplemental steam turbine. Thermal efficiencies of current IGCC power plants range from 39% to 42% (HHV basis) or ≈42–45% (LHV basis) for bituminous coal and assuming utilization of mainstream gasification technologies (Shell, GE Gasifier, CB&I). IGCC power plants outperform conventional pulverized coal-fueled plants in terms of pollutant emissions, and allow for relatively easy carbon capture.

At least 40% of the world's electricity comes from coal, and in 2016, 30% of the United States' electricity came from coal, down from approximately 49% in 2008. As of 2012 in the United States, use of coal to generate electricity was declining, as plentiful supplies of natural gas obtained by hydraulic fracturing of tight shale formations became available at low prices.

In Denmark, a net electric efficiency of >47% has been obtained at the coal-fired Nordjyllandsværket CHP Plant and an overall plant efficiency of up to 91% with cogeneration of electricity and district heating. The multifuel-fired Avedøreværket CHP Plant just outside Copenhagen can achieve a net electric efficiency as high as 49%. The overall plant efficiency with cogeneration of electricity and district heating can reach as much as 94%.

An alternative form of coal combustion is as coal-water slurry fuel (CWS), which was developed in the Soviet Union. Other ways to use coal are combined heat and power cogeneration and an MHD topping cycle.

The total known deposits recoverable by current technologies, including highly polluting, low-energy content types of coal (i.e., lignite, bituminous), is sufficient for many years. Consumption is increasing and maximal production could be reached within decades . On the other hand, much may have to be left in the ground to avoid climate change.

Switch to natural gas

Worldwide natural gas generated power has increased from 740 TW in 1973 to 5140 TW in 2014, generating 22% of the worlds total electricity, approximately half as much as generated with coal. In addition to generating electricity, natural gas is also popular in some countries for heating and as an automotive fuel.

The use of coal in the United Kingdom declined as a result of the development of North Sea oil and the subsequent Dash for Gas from the 1990s to 2000.

In Canada some coal power plants such as the Hearn Generating Station have stopped burning coal by switching the plant to natural gas.

In the United States, 27 gigawatts of capacity from coal-fired generators was slated to be retired from 175 US coal-fired power plants between 2012 and 2016. Natural gas showed a corresponding jump, increasing by a third over 2011. Coal's share of US electricity generation dropped to just over 36%. Due to emergence of shale gas, coal consumption declined from 2009. Natural gas accounted for 81% of new power generation in the US between 2000 and 2010. Coal-fired generation puts out about twice the amount of carbon dioxide—around 2,000 pounds for every megawatt hour generated—than electricity generated by burning natural gas at 1,100 pounds of greenhouse gas per megawatt hour. As the fuel mix in the United States has changed to reduce coal and increase natural gas generation, carbon dioxide emissions have unexpectedly fallen. Those measured in the first quarter of 2012 were the lowest of any recorded for the first quarter of any year since 1992.

Coke is a solid carbonaceous residue derived from coking coal (a low-ash, low-sulfur bituminous coal, also known as metallurgical coal), which is used in manufacturing steel and other iron products. Coke is made from coking coal by baking in an oven without oxygen at temperatures as high as 1,000 °C (1,832 °F), driving off the volatile constituents and fusing together the fixed carbon and residual ash. Metallurgical coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace. The result is pig iron, and is too rich in dissolved carbon, so it must be treated further to make steel.

Coking coal should be low in ash, sulfur, and phosphorus, so that these do not migrate to the metal. Based on the ash percentage, the coking coal can be divided into various grades. These grades are:

- Steel Grade I (Ash content not exceeding 15%)
- Steel Grade II (Exceeding 15% but not exceeding 18%)
- Washery Grade I (Exceeding 18% but not exceeding 21%)
- Washery Grade II (Exceeding 21% but not exceeding 24%)
- Washery Grade III (Exceeding 24% but not exceeding 28%)
- Washery Grade IV (Exceeding 28% but not exceeding 35%)

The coke must be strong enough to resist the weight of overburden in the blast furnace, which is why coking coal is so important in making steel using the conventional route. However, the alternative route is direct reduced iron, where any carbonaceous fuel can be used to make sponge or pelletised iron. Coke from coal is grey, hard, and porous and has a heating value of 24.8 million Btu/ton (29.6 MJ/kg). Some cokemaking processes produce valuable byproducts, including coal tar, ammonia, light oils, and coal gas.

Petroleum coke is the solid residue obtained in oil refining, which resembles coke, but contains too many impurities to be useful in metallurgical applications.

Coal can also be converted into synthetic fuels equivalent to gasoline or diesel by several different direct processes (which do not intrinsically require gasification or indirect conversion). In the direct liquefaction processes, the coal is either hydrogenated or carbonized. Hydrogenation processes are the Bergius process, the SRC-I and SRC-II (Solvent Refined Coal) processes, the NUS Corporation hydrogenation process and several other single-stage and two-stage processes. In the process of low-temperature carbonization, coal is coked at temperatures between 360 and 750 °C (680 and 1,380 °F). These temperatures optimize the production of coal tars richer in lighter hydrocarbons than normal coal tar. The coal tar is then further processed into fuels. An overview of coal liquefaction and its future potential is available.

Coal liquefaction methods involve carbon dioxide (CO_2) emissions in the conversion process. If coal liquefaction is done without employing either carbon capture and storage (CCS) technologies or biomass blending, the result is lifecycle greenhouse gas footprints that are generally greater than those released in the extraction and refinement of liquid fuel production from crude oil. If CCS technologies are employed, reductions of 5–12% can be achieved in Coal to Liquid (CTL) plants and up to a 75% reduction is achievable when co-gasifying coal with commercially demonstrated levels of biomass (30% biomass by weight) in coal/biomass-to-liquids plants. For future synthetic fuel projects, carbon dioxide sequestration is proposed to avoid releasing CO_2 into the atmosphere. Sequestration adds to the cost of production.

Refined coal is the product of a coal-upgrading technology that removes moisture and certain pollutants from lower-rank coals such as sub-bituminous and lignite (brown) coals. It is one form of several precombustion treatments and processes for coal that alter coal's characteristics before it is burned. The goals of precombustion coal technologies are to increase efficiency and reduce emissions when the coal is burned. Depending on the situation, precombustion technology can be used in place of or as a supplement to postcombustion technologies to control emissions from coal-fueled boilers.

Industrial processes

Finely ground bituminous coal, known in this application as sea coal, is a constituent of foundry sand. While the molten metal is in the mould, the coal burns slowly, releasing reducing gases at pressure, and so preventing the metal from penetrating the pores of the sand. It is also contained in 'mould wash', a paste or liquid with the same function applied to the mould before casting. Sea coal can be mixed with the clay lining (the "bod") used for the bottom of a cupola furnace. When heated, the coal decomposes and the bod becomes slightly friable, easing the process of breaking open holes for tapping the molten metal.

Coal is an important feedstock in production of a wide range of chemical fertilizers and other chemical products. The main route to these products is coal gasification to produce syngas. Primary chemicals that are produced directly from the syngas include methanol, hydrogen and carbon monoxide, which are the chemical building blocks from which a whole spectrum of derivative chemicals are manufactured, including olefins, acetic acid, formaldehyde, ammonia, urea and others. The

versatility of syngas as a precursor to primary chemicals and high-value derivative products provides the option of using relatively inexpensive coal to produce a wide range of valuable commodities.

Historically, production of chemicals from coal has been used since the 1950s and has become established in the market. According to the 2010 Worldwide Gasification Database, a survey of current and planned gasifiers, from 2004 to 2007 chemical production increased its gasification product share from 37% to 45%. From 2008 to 2010, 22% of new gasifier additions were to be for chemical production.

Because the slate of chemical products that can be made via coal gasification can in general also use feedstocks derived from natural gas and petroleum, the chemical industry tends to use whatever feedstocks are most cost-effective. Therefore, interest in using coal tends to increase for higher oil and natural gas prices and during periods of high global economic growth that may strain oil and gas production. Also, production of chemicals from coal is of much higher interest in countries like South Africa, China, India and the United States where there are abundant coal resources. The abundance of coal combined with lack of natural gas resources in China is strong inducement for the coal to chemicals industry pursued there. In the United States, the best example of the industry is Eastman Chemical Company which has been successfully operating a coal-to-chemicals plant at its Kingsport, Tennessee, site since 1983. Similarly, Sasol has built and operated coal-to-chemicals facilities in South Africa.

Coal to chemical processes do require substantial quantities of water. As of 2013 much of the coal to chemical production was in the People's Republic of China where environmental regulation and water management was weak.

Clean coal technology

"Clean" coal technology is a collection of technologies being developed to mitigate the environmental impact of coal energy generation. Those technologies are being developed to remove or reduce pollutant emissions to the atmosphere. Some of the techniques that would be used to accomplish this include chemically washing minerals and impurities from the coal, gasification , improved technology for treating flue gases to remove pollutants to increasingly stringent levels and at higher efficiency, carbon capture and storage technologies to capture the carbon dioxide from the flue gas and dewatering lower rank coals (brown coals) to improve the calorific value, and thus the efficiency of the conversion into electricity. Figures from the United States Environmental Protection Agency show that these technologies have

made today's coal-based generating fleet 77 percent cleaner on the basis of regulated emissions per unit of energy produced.

Clean coal technology usually addresses atmospheric problems resulting from burning coal. Historically, the primary focus was on SO_2 and NO_x, the most important gases in causation of acid rain, and particulates which cause visible air pollution and deleterious effects on human health. More recent focus has been on carbon dioxide (due to its impact on global warming) and concern over toxic species such as mercury. Concerns exist regarding the economic viability of these technologies and the timeframe of delivery, potentially high hidden economic costs in terms of social and environmental damage, and the costs and viability of disposing of removed carbon and other toxic matter.

Several different technological methods are available for the purpose of carbon capture as demanded by the clean coal concept:

- Pre-combustion capture – This involves gasification of a feedstock (such as coal) to form synthesis gas, which may be shifted to produce a H_2 and CO_2-rich gas mixture, from which the CO_2 can be efficiently captured and separated, transported, and ultimately sequestered, This technology is usually associated with Integrated Gasification Combined Cycle process configurations.
- Post-combustion capture – This refers to capture of CO_2 from exhaust gases of combustion processes, typically using sorbents, solvents, or membrane separations to remove CO_2 from the bulk gases.
- Oxy-fuel combustion – Fossil fuels such as coal are burned in a mixture of recirculated flue gas and oxygen, rather than in air, which largely eliminates nitrogen from the flue gas enabling efficient, low-cost CO_2 capture.

The Kemper County IGCC Project, a 582 MW coal gasification-based power plant, will use pre-combustion capture of CO_2 to capture 65% of the CO_2 the plant produces, which will be utilized/geologically sequestered in enhanced oil recovery operations. If the technology used at the Kemper Project is successful, it will be the United States' first clean coal plant.

The Saskatchewan Government's Boundary Dam Power Station Integrated Carbon Capture and Sequestration Demonstration Project will use post-combustion, amine-based scrubber technology to capture 90% of the CO_2 emitted by Unit 3 of the power plant; this CO_2 will be pipelined to and utilized for enhanced oil recovery in the Weyburn oil fields. However, only about a half of this CO2 will actually be permanently stored, the remainder is released into the atmosphere during capturing, and the processing in the oil field.

An early example of a coal-based plant using (oxy-fuel) carbon-capture technology is Swedish company Vattenfall's Schwarze Pumpe power station located in Spremberg, Germany, built by German firm Siemens, which went on-line in September 2008. The facility captures CO_2 and acid rain producing pollutants, separates them, and compresses the CO_2 into a liquid. Plans are to inject the CO_2 into depleted natural gas fields or other geological formations. Vattenfall opines that this technology is considered not to be a final solution for CO_2 reduction in the atmosphere, but provides an achievable solution in the near term while more desirable alternative solutions to power generation can be made economically practical. In 2014 research and development were discontinued due to high costs making the technology unviable.

Economic aspects

Coal (by liquefaction technology) is one of the backstop resources that could limit escalation of oil prices and mitigate the effects of transportation energy shortage that will occur under peak oil. This is contingent on liquefaction production capacity becoming large enough to satiate the very large and growing demand for petroleum. Estimates of the cost of producing liquid fuels from coal suggest that domestic U.S. production of fuel from coal becomes cost-competitive with oil priced at around $35 per barrel, with the $35 being the break-even cost. With oil prices as low as around $40 per barrel in the U.S. as of December 2008, liquid coal lost some of its economic allure in the U.S., but will probably be re-vitalized, similar to oil sand projects, with an oil price around $70 per barrel.

In China, due to an increasing need for liquid energy in the transportation sector, coal liquefaction projects were given high priority even during periods of oil prices below $40 per barrel. This is probably because China prefers not to be dependent on foreign oil, instead utilizing its enormous domestic coal reserves. As oil prices were increasing during the first half of 2009, the coal liquefaction projects in China were again boosted, and these projects are profitable with an oil barrel price of $40.

China is the largest producer of coal in the world. It is the world's largest energy consumer, and relies on coal to supply 69% of its energy needs. An estimated 5 million people worked in China's coal-mining industry in 2007.

Coal pollution costs the EU €43 billion each year. Measures to cut air pollution may have beneficial long-term economic impacts for individuals.

Market trends

In 2006, China was the top producer of coal with 38% share followed by the United States and India, according to the British Geological Survey. As of 2012 coal production in the United States was falling at the rate of 7% annually with many power plants using coal shut down or converted to natural gas; however, some of the reduced domestic demand was taken up by increased exports with five coal export terminals being proposed in the Pacific Northwest to export coal from the Powder River Basin to China and other Asian markets; however, as of 2013, environmental opposition was increasing. High-sulfur coal mined in Illinois which was unsaleable in the United States found a ready market in Asia as exports reached 13 million tons in 2012.

Oil

Types

Organic oils

Organic oils are produced in remarkable diversity by plants, animals, and other organisms through natural metabolic processes. *Lipid* is the scientific term for the fatty acids, steroids and similar chemicals often found in the oils produced by living things, while oil refers to an overall mixture of chemicals. Organic oils may also contain chemicals other than lipids, including proteins, waxes (class of compounds with oil-like properties that are solid at common temperatures) and alkaloids.

Lipids can be classified by the way that they are made by an organism, their chemical structure and their limited solubility in water compared to oils. They have a high carbon and hydrogen content and are considerably lacking in oxygen compared to other organic compounds and minerals; they tend to be relatively nonpolar molecules, but may include both polar and nonpolar regions as in the case of phospholipids and steroids.

Mineral oils

Crude oil, or petroleum, and its refined components, collectively termed *petrochemicals*, are crucial resources in the modern economy. Crude oil originates from ancient fossilized organic materials, such as zooplankton and algae, which geochemical processes convert into oil. The name "mineral oil" is a misnomer, in that minerals are not the source of the oil—ancient plants and animals are. Mineral oil is organic. However, it is classified as "mineral oil" instead of as "organic oil" because its organic origin is remote (and was unknown at the time of its discovery), and because it is obtained in the vicinity of rocks, underground traps, and sands. *Mineral oil* also refers to several specific distillates of crude oil.

Some oils burn in liquid or aerosol form, generating light, and heat which can be used directly or converted into other forms of energy such as electricity or mechanical

work. To obtain many fuel oils, crude oil is pumped from the ground and is shipped via oil tanker or a pipeline to an oil refinery. There, it is converted from crude oil to diesel fuel (petrodiesel), ethane (and other short-chain alkanes), fuel oils(heaviest of commercial fuels, used in ships/furnaces), gasoline (petrol), jet fuel, kerosene, benzene (historically), and liquefied petroleum gas. A 42-gallon barrel (U.S.) of crude oil produces approximately 10 gallons of diesel, 4 gallons of jet fuel, 19 gallons of gasoline, 7 gallons of other products, 3 gallons split between heavy fuel oil and liquified petroleum gases, and 2 gallons of heating oil. The total production of a barrel of crude into various products results in an increase to 45 gallons. Not all oils used as fuels are mineral oils.

In the 18th and 19th centuries, whale oil was commonly used for lamps, which was replaced with natural gas and then electricity.

Crude oil can be refined into a wide variety of component hydrocarbons. *Petrochemicals* are the refined components of crude oil and the chemical products made from them. They are used as detergents, fertilizers, medicines, paints, plastics, synthetic fibers, and synthetic rubber.

Organic oils are another important chemical feedstock, especially in green chemistry.

Natural gas

Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other higher alkanes, and sometimes a small percentage of carbon dioxide, nitrogen, hydrogen sulfide, or helium. It is formed when layers of decomposing plant and animal matter are exposed to intense heat and pressure under the surface of the Earth over millions of years. The energy that the plants originally obtained from the sun is stored in the form of chemical bonds in the gas.

Natural gas is a fossil fuel used as a source of energy for heating, cooking, and electricity generation. It is also used as a fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals. Fossil fuel based natural gas is a non-renewable resource.

Natural gas is found in deep underground rock formations or associated with other hydrocarbon reservoirs in coal beds and as methane clathrates. Petroleum is another resource and fossil fuel found in close proximity to and with natural gas. Most natural gas was created over time by two mechanisms: biogenic and thermogenic. Biogenic gas is created by methanogenic organisms in marshes, bogs, landfills, and shallow sediments. Deeper in the earth, at greater temperature and pressure, thermogenic gas is created from buried organic material.

In petroleum production gas is often burnt as flare gas. The World Bank estimates that over 150 cubic kilometers of natural gas are flared or vented annually. Before natural gas can be used as a fuel, most, but not all, must be processed to remove impurities, including water, to meet the specifications of marketable natural gas. The by-products of this processing include: ethane, propane, butanes, pentanes, and higher molecular weight hydrocarbons, hydrogen sulfide (which may be converted into pure sulfur), carbon dioxide, water vapor, and sometimes helium and nitrogen.

Natural gas is often informally referred to simply as "gas", especially when compared to other energy sources such as oil or coal. However, it is not to be confused with gasoline, especially in North America, where the term gasoline is often shortened in colloquial usage to *gas*.

Natural gas was discovered accidentally in ancient China, as it resulted from the drilling for brines. The natural gas was used to boil brine to make salt. Natural gas was first used by the Chinese in about 500 BC (possibly even 1000 BC). They discovered a way to transport gas seeping from the ground in crude pipelines of bamboo to where it was used to boil salt water to extract the salt, in the Ziliujing District of Sichuan. The world's first industrial extraction of natural gas started at Fredonia, New York, United States, in 1825. By 2009, 66 000 km³ (or 8%) had been used out of the total 850 000 km³ of estimated remaining recoverable reserves of natural gas. Based on an estimated 2015 world consumption rate of about 3400 km³ of gas per year, the total estimated remaining economically recoverable reserves of natural gas would last 250 years at current consumption rates. An annual increase in usage of 2–3% could result in currently recoverable reserves lasting significantly less, perhaps as few as 80 to 100 years.

In the 19th century, natural gas was usually obtained as a by-product of producing oil, since the small, light gas carbon chains came out of solution as the extracted fluids underwent pressure reduction from the reservoir to the surface, similar to uncapping a soft drink bottle where the carbon dioxide effervesces. Unwanted natural gas was a disposal problem in the active oil fields. If there was not a market for natural gas near the wellhead it was prohibitively expensive to pipe to the end user.

In the 19th century and early 20th century, unwanted gas was usually burned off at oil fields. Today, unwanted gas (or stranded gas without a market) associated with oil extraction often is returned to the reservoir with 'injection' wells while awaiting a possible future market or to repressurize the formation, which can enhance extraction rates from other wells. In regions with a high natural gas demand (such as the US), pipelines are constructed when it is economically feasible to transport gas from a wellsite to an end consumer.

In addition to transporting gas via pipelines for use in power generation, other end uses for natural gas include export as liquefied natural gas (LNG) or conversion of natural gas into other liquid products via gas to liquids (GTL) technologies. GTL technologies can convert natural gas into liquids products such as gasoline, diesel or jet fuel. A variety of GTL technologies have been developed, including Fischer–Tropsch (F–T), methanol to gasoline (MTG) and syngas to gasoline plus (STG+). F–T produces a synthetic crude that can be further refined into finished products, while MTG can produce synthetic gasoline from natural gas. STG+ can produce drop-in gasoline, diesel, jet fuel and aromatic chemicals directly from natural gas via a single-loop process. In 2011, Royal Dutch Shell's 140,000 barrels (22,000 m^3) per day F–T plant went into operation in Qatar.

Natural gas can be "associated" (found in oil fields), or "non-associated" (isolated in natural gas fields), and is also found in coal beds (as coalbed methane). It sometimes contains a significant amount of ethane, propane, butane, and pentane—heavier hydrocarbons removed for commercial use prior to the methane being sold as a consumer fuel or chemical plant feedstock. Non-hydrocarbons such as carbon dioxide, nitrogen, helium (rarely), and hydrogen sulfide must also be removed before the natural gas can be transported.

Natural gas extracted from oil wells is called casinghead gas (whether or not truly produced up the annulus and through a casinghead outlet) or associated gas. The natural gas industry is extracting an increasing quantity of gas from challenging resource types: sour gas, tight gas, shale gas, and coalbed methane.

There is some disagreement on which country has the largest proven gas reserves. Sources that consider that Russia has by far the largest proven reserves include the US CIA (47 600 km^3), the US Energy Information Administration (47 800 km^3),and OPEC (48 700 km^3). However, BP credits Russia with only 32 900 km^3,which would place it in second place, slightly behind Iran (33 100 to 33 800 km^3, depending on the source). With Gazprom, Russia is frequently the world's largest natural gas extractor. Major proven resources (in cubic kilometers) are world 187 300 (2013), Iran 33 600 (2013), Russia 32 900 (2013), Qatar 25 100 (2013), Turkmenistan 17 500 (2013) and the United States 8500 (2013).

It is estimated that there are about 900 000 km^3 of "unconventional" gas such as shale gas, of which 180 000 km^3 may be recoverable. In turn, many studies from MIT, Black & Veatch and the DOE predict that natural gas will account for a larger portion of electricity generation and heat in the future.

The world's largest gas field is the offshore South Pars / North Dome Gas-Condensate field, shared between Iran and Qatar. It is estimated to have 51,000 cubic kilometers (12,000 cu mi) of natural gas and 50 billion barrels (7.9 billion cubic meters) of natural gas condensates.

Because natural gas is not a pure product, as the reservoir pressure drops when non-associated gas is extracted from a field under supercritical (pressure/temperature) conditions, the higher molecular weight components may partially condense upon isothermic depressurizing—an effect called retrograde condensation. The liquid thus formed may get trapped as the pores of the gas reservoir get depleted. One method to deal with this problem is to re-inject dried gas free of condensate to maintain the underground pressure and to allow re-evaporation and extraction of condensates. More frequently, the liquid condenses at the surface, and one of the tasks of the gas

plant is to collect this condensate. The resulting liquid is called natural gas liquid (NGL) and has commercial value.

Shale gas is natural gas produced from shale. Because shale has matrix permeability too low to allow gas to flow in economical quantities, shale gas wells depend on fractures to allow the gas to flow. Early shale gas wells depended on natural fractures through which gas flowed; almost all shale gas wells today require fractures artificially created by hydraulic fracturing. Since 2000, shale gas has become a major source of natural gas in the United States and Canada. Because of increased shale gas production, the United States is now the number one natural gas producer in the world. Following the success in the United States, shale gas exploration is beginning in countries such as Poland, China, and South Africa.

Town gas is a flammable gaseous fuel made by the destructive distillation of coal. It contains a variety of calorific gases including hydrogen, carbon monoxide, methane, and other volatile hydrocarbons, together with small quantities of non-calorific gases such as carbon dioxide and nitrogen, and is used in a similar way to natural gas. This is a historical technology and is not usually economically competitive with other sources of fuel gas today.

Most town "gashouses" located in the eastern US in the late 19th and early 20th centuries were simple by-product coke ovens that heated bituminous coal in air-tight chambers. The gas driven off from the coal was collected and distributed through networks of pipes to residences and other buildings where it was used for cooking and lighting. (Gas heating did not come into widespread use until the last half of the 20th century.) The coal tar (or asphalt) that collected in the bottoms of the gashouse ovens was often used for roofing and other waterproofing purposes, and when mixed with sand and gravel was used for paving streets.

Methanogenic archaea are responsible for all biological sources of methane. Some live in symbiotic relationships with other life forms, including termites, ruminants, and cultivated crops. Other sources of methane, the principal component of natural gas, include landfill gas, biogas, and methane hydrate. When methane-rich gases are produced by the anaerobic decay of non-fossil organic matter (biomass), these are referred to as biogas (or natural biogas). Sources of biogas include swamps, marshes, and landfills, as well as agricultural waste materials such
as sewage sludge and manure by way of anaerobic digesters, in addition to enteric fermentation, particularly in cattle. Landfill gas is created by decomposition of waste in landfill sites. Excluding water vapor, about half of landfill gas is methane and most of the rest is carbon dioxide, with small amounts of nitrogen, oxygen, and hydrogen,

and variable trace amounts of hydrogen sulfide and siloxanes. If the gas is not removed, the pressure may get so high that it works its way to the surface, causing damage to the landfill structure, unpleasant odor, vegetation die-off, and an explosion hazard. The gas can be vented to the atmosphere, flared or burned to produce electricity or heat. Biogas can also be produced by separating organic materials from waste that otherwise goes to landfills. This method is more efficient than just capturing the landfill gas it produces. Anaerobic lagoonsproduce biogas from manure, while biogas reactors can be used for manure or plant parts. Like landfill gas, biogas is mostly methane and carbon dioxide, with small amounts of nitrogen, oxygen and hydrogen. However, with the exception of pesticides, there are usually lower levels of contaminants.

Landfill gas cannot be distributed through utility natural gas pipelines unless it is cleaned up to less than 3% CO_2, and a few parts per million H_2S, because CO_2 and H_2S corrode the pipelines. The presence of CO_2 will lower the energy level of the gas below requirements for the pipeline. Siloxanes in the gas will form deposits in gas burners and need to be removed prior to entry into any gas distribution or transmission system. Consequently, it may be more economical to burn the gas on site or within a short distance of the landfill using a dedicated pipeline. Water vapor is often removed, even if the gas is burned on site. If low temperatures condense water out of the gas, siloxanes can be lowered as well because they tend to condense out with the water vapor. Other non-methane components may also be removed to meet emission standards, to prevent fouling of the equipment or for environmental considerations. Co-firing landfill gas with natural gas improves combustion, which lowers emissions.

Biogas, and especially landfill gas, are already used in some areas, but their use could be greatly expanded. Experimental systems were being proposed for use in parts of Hertfordshire, UK, and Lyonin France. Using materials that would otherwise generate no income, or even cost money to get rid of, improves the profitability and energy balance of biogas production. Gas generated in sewage treatment plants is commonly used to generate electricity. For example, the Hyperion sewage plant in Los Angeles burns 8 million cubic feet (230,000 cubic meters) of gas per day to generate power New York City utilizes gas to run equipment in the sewage plants, to generate electricity, and in boilers. Using sewage gas to make electricity is not limited to large cities. The city of Bakersfield, California, uses cogeneration at its sewer plants. California has 242 sewage wastewater treatment plants, 74 of which have

installed anaerobic digesters. The total biopower generation from the 74 plants is about 66 MW.

Huge quantities of natural gas (primarily methane) exist in the form of hydrates under sediment on offshore continental shelves and on land in arctic regions that experience permafrost, such as those in Siberia. Hydrates require a combination of high pressure and low temperature to form.

In 2010, the cost of extracting natural gas from crystallized natural gas was estimated to be as much as twice the cost of extracting natural gas from conventional sources, and even higher from offshore deposits.

In 2013, Japan Oil, Gas and Metals National Corporation (JOGMEC) announced that they had recovered commercially relevant quantities of natural gas from methane hydrate.

Because of its low density, it is not easy to store natural gas or to transport it by vehicle. Natural gas pipelines are impractical across oceans, since the gas needs to be cooled down and compressed, as the friction in the pipeline causes the gas to heat up. Many existing pipelines in America are close to reaching their capacity, prompting some politicians representing northern states to speak of potential shortages. The large trade cost implies that natural gas markets are globally much less integrated, causing significant price differences across countries. In Western Europe, the gas pipeline network is already dense. New pipelines are planned or under construction in Eastern Europe and between gas fields in Russia, Near East and Northern Africa and Western Europe.

Whenever gas is bought or sold at custody transfer points, rules and agreements are made regarding the gas quality. These may include the maximum allowable concentration of CO_2, H_2S and H_2O. Usually sales quality gas that has been treated to remove contamination is traded on a "dry gas" basis and is required to be commercially free from objectionable odours, materials, and dust or other solid or liquid matter, waxes, gums and gum forming constituents, which might damage or adversely affect operation of equipment downstream of the custody transfer point.

LNG carriers transport liquefied natural gas (LNG) across oceans, while tank trucks can carry liquefied or compressed natural gas (CNG) over shorter distances. Sea transport using CNG carrier ships that are now under development may be competitive with LNG transport in specific conditions.

Gas is turned into liquid at a liquefaction plant, and is returned to gas form at regasification plant at the terminal. Shipborne regasification equipment is also used.

LNG is the preferred form for long distance, high volume transportation of natural gas, whereas pipeline is preferred for transport for distances up to 4,000 km (2,500 mi) over land and approximately half that distance offshore.

CNG is transported at high pressure, typically above 200 bars (20,000 kPa; 2,900 psi). Compressors and decompression equipment are less capital intensive and may be economical in smaller unit sizes than liquefaction/regasification plants. Natural gas trucks and carriers may transport natural gas directly to end-users, or to distribution points such as pipelines.

In the past, the natural gas which was recovered in the course of recovering petroleum could not be profitably sold, and was simply burned at the oil field in a process known as flaring. Flaring is now illegal in many countries. Additionally, higher demand in the last 20–30 years has made production of gas associated with oil economically viable. As a further option, the gas is now sometimes re-injected into the formation for enhanced oil recovery by pressure maintenance as well as miscible or immiscible flooding. Conservation, re-injection, or flaring of natural gas associated with oil is primarily dependent on proximity to markets (pipelines), and regulatory restrictions.

Natural gas can be indirectly exported through the absorption in other physical output. A recent study suggests that the expansion of shale gas production in the US has caused prices to drop relative to other countries. This has caused a boom in energy intensive manufacturing sector exports, whereby the average dollar unit of US manufacturing exports has almost tripled its energy content between 1996 and 2012.

A "master gas system" was invented in Saudi Arabia in the late 1970s, ending any necessity for flaring. Satellite observation, however, shows that flaring and venting are still practiced in some gas-extracting countries.

Natural gas is used to generate electricity and heat for desalination. Similarly, some landfills that also discharge methane gases have been set up to capture the methane and generate electricity.

Natural gas is often stored underground inside depleted gas reservoirs from previous gas wells, salt domes, or in tanks as liquefied natural gas. The gas is injected in a time of low demand and extracted when demand picks up. Storage nearby end users helps to meet volatile demands, but such storage may not always be practicable.

With 15 countries accounting for 84% of the worldwide extraction, access to natural gas has become an important issue in international politics, and countries vie for control of pipelines. In the first decade of the 21st century, Gazprom, the state-owned

energy company in Russia, engaged in disputes with Ukraine and Belarus over the price of natural gas, which have created concerns that gas deliveries to parts of Europe could be cut off for political reasons. The United States is preparing to export natural gas.

Floating liquefied natural gas (FLNG) is an innovative technology designed to enable the development of offshore gas resources that would otherwise remain untapped due to environmental or economic factors it is nonviable to develop them via a land-based LNG operation. FLNG technology also provides a number of environmental and economic advantages:

- Environmental – Because all processing is done at the gas field, there is no requirement for long pipelines to shore, compression units to pump the gas to shore, dredging and jetty construction, and onshore construction of an LNG processing plant, which significantly reduces the environmental footprint. Avoiding construction also helps preserve marine and coastal environments. In addition, environmental disturbance will be minimised during decommissioning because the facility can easily be disconnected and removed before being refurbished and re-deployed elsewhere.
- Economic – Where pumping gas to shore can be prohibitively expensive, FLNG makes development economically viable. As a result, it will open up new business opportunities for countries to develop offshore gas fields that would otherwise remain stranded, such as those offshore East Africa.

Many gas and oil companies are considering the economic and environmental benefits of floating liquefied natural gas (FLNG). There are currently projects underway to construct five FLNG facilities. Petronas is close to completion on their FLNG-1 at Daewoo Shipbuilding and Marine Engineering and are underway on their FLNG-2 project at Samsung Heavy Industries. Shell Prelude is due to start production 2017. The Browse LNG project will commence FEED in 2019.

Natural gas is primarily used in the northern hemisphere. North America and Europe are major consumers.

Mid-stream natural gas

Often well head gases require removal of various hydrocarbon molecules contained within the gas. Some of these gases include heptane, pentane, propane and other hydrocarbons with molecular weights above methane (CH_4). The natural gas transmission lines extend to the natural gas processing plant or unit which removes the higher molecular weighted hydrocarbons to produce natural gas with energy content between 950–1,050 British thermal units per cubic foot (35–39 MJ/m^3). The processed natural gas may then be used for residential, commercial and industrial uses.

Natural gas flowing in the distribution lines is called mid-stream natural gas and is often used to power engines which rotate compressors. These compressors are required in the transmission line to pressurize and re-pressurize the mid-stream natural gas as the gas travels. Typically, natural gas powered engines require 950–1,050 BTU/cu ft (35–39 MJ/m^3) natural gas to operate at the rotational name plate specifications. Several methods are used to remove these higher molecular weighted gases for use by the natural gas engine. A few technologies are as follows:

- Joule–Thomson skid
- Cryogenic or chiller system
- Chemical enzymology system

Power generation

Natural gas is a major source of electricity generation through the use of cogeneration, gas turbines and steam turbines. Natural gas is also well suited for a combined use in association with renewable energysources such as wind or solar and for alimenting peak-load power stations functioning in tandem with hydroelectric plants. Most grid peaking power plants and some off-grid engine-generators use natural gas. Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. Natural gas burns more cleanly than other fuels, such as oil and coal. Because burning natural gas produces both water and carbon dioxide, it produces less carbon dioxide per unit of energy released than coal, which produces mostly carbon dioxide. Burning natural gas produces only about half the carbon dioxide per kilowatt-hour (kWh) that coal does.

For transportation, burning natural gas produces about 30% less carbon dioxide than burning petroleum. The US Energy Information Administration reports the following emissions in million metric tons of carbon dioxide in the world for 2012:

Natural gas: 6,799

- Petroleum: 11,695
- Coal: 13,787

Coal-fired electric power generation emits around 2,000 pounds (900 kg) of carbon dioxide for every megawatt-hour (MWh) generated, which is almost double the carbon dioxide released by natural gas-fired generation. Because of this higher carbon efficiency of natural gas generation, as the fuel mix in the United States has changed to reduce coal and increase natural gas generation, carbon dioxide emissions have unexpectedly fallen. Those measured in the first quarter of 2012 were the lowest of any recorded for the first quarter of any year since 1992.

Combined cycle power generation using natural gas is currently the cleanest available source of power using hydrocarbon fuels, and this technology is widely and increasingly used as natural gas can be obtained at increasingly reasonable costs. Fuel cell technology may eventually provide cleaner options for converting natural gas into electricity, but as yet it is not price-competitive. Locally produced electricity and heat using natural gas powered Combined Heat and Power plant (CHP or Cogeneration plant) is considered energy efficient and a rapid way to cut carbon emissions.

Natural gas generated power has increased from 740 TWh in 1973 to 5140 TWh in 2014, generating 22% of the worlds total electricity. Approximately half as much as generated with coal. Efforts around the world to reduce the use of coal has led some regions to switch to natural gas.

Domestic use

Natural gas dispensed in a residential setting can generate temperatures in excess of 1,100 °C (2,000 °F) making it a powerful domestic cooking and heating fuel. In much of the developed world it is supplied through pipes to homes, where it is used for many purposes including ranges and ovens, gas-heated clothes dryers, heating/cooling, and central heating. Heaters in homes and other buildings may include boilers, furnaces, and water heaters. Both North America and Europe are major consumers of natural gas.

Domestic appliances, furnaces, and boilers use low pressure, usually 6 to 7 inches of water (6" to 7" WC), which is about 0.25 psig. The pressures in the supply lines vary, either utilization pressure (UP, the aforementioned 6" to 7" WC) or elevated pressure (EP), which may be anywhere from 1 psig to 120 psig. Systems using EP have a regulator at the service entrance to step down the pressure to UP.

In the US compressed natural gas (CNG) is used in rural homes without connections to piped-in public utility services, or with portable grills. Natural gas is also supplied by independent natural gas suppliers through Natural Gas Choice programs throughout the United States. However, as CNG costs more than LPG (liquefied petroleum gas), LPG is the dominant source of rural gas.

Transportation

CNG is a cleaner and also cheaper alternative to other automobile fuels such as gasoline (petrol) and diesel. By the end of 2014 there were over 20 million natural gas vehicles worldwide, led by Iran (3.5 million), China (3.3 million), Pakistan (2.8 million), Argentina (2.5 million), India (1.8 million), and Brazil (1.8 million). The energy efficiency is generally equal to that of gasoline engines, but lower compared with modern diesel engines. Gasoline/petrol vehicles converted to run on natural gas suffer because of the low compression ratio of their engines, resulting in a cropping of delivered power while running on natural gas (10%–15%). CNG-specific engines, however, use a higher compression ratio due to this fuel's higher octane number of 120–130.

Besides use in road vehicles, CNG can also be used in aircraft. Compressed natural gas has been used in some aircraft like the Aviat Aircraft Husky 200 CNG and the Chromarat VX-1 KittyHawk

LNG is also being used in aircraft. Russian aircraft manufacturer Tupolev for instance is running a development program to produce LNG- and hydrogen-powered aircraft. The program has been running since the mid-1970s, and seeks to develop LNG and hydrogen variants of the Tu-204 and Tu-334 passenger aircraft, and also the Tu-330 cargo aircraft. Depending on the current market price for jet fuel and LNG, fuel for an LNG-powered aircraft could cost 5,000 rubles (US$100) less per tonne, roughly 60%, with considerable reductions to carbon monoxide, hydrocarbon and nitrogen oxide emissions.

The advantages of liquid methane as a jet engine fuel are that it has more specific energy than the standard kerosene mixes do and that its low temperature can help cool the air which the engine compresses for greater volumetric efficiency, in effect

replacing an intercooler. Alternatively, it can be used to lower the temperature of the exhaust.

Fertilizers

Natural gas is a major feedstock for the production of ammonia, via the Haber process, for use in fertilizer production.

Hydrogen

Natural gas can be used to produce hydrogen, with one common method being the hydrogen reformer. Hydrogen has many applications: it is a primary feedstock for the chemical industry, a hydrogenating agent, an important commodity for oil refineries, and the fuel source in hydrogen vehicles.

Animal and fish feed

Protein rich animal and fish feed is produced by feeding natural gas to Methylococcus capsulatus bacteria on commercial scale.

Other

Natural gas is also used in the manufacture of fabrics, glass, steel, plastics, paint, and other products.

Natural gas is mainly composed of methane. After release to the atmosphere it is removed by gradual oxidation to carbon dioxide and water by hydroxyl radicals (OH^-) formed in the troposphere or stratosphere, giving the overall chemical reaction $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. While the lifetime of atmospheric methane is relatively short when compared to carbon dioxide, with a half-life of about 7 years, it is more efficient at trapping heat in the atmosphere, so that a given quantity of methane has 84 times the global-warming potential of carbon dioxide over a 20-year period and 28 times over a 100-year period. Natural gas is thus a more potent greenhouse gas than carbon dioxide due to the greater global-warming potential of methane. 2009 estimates by

the EPA place global emissions of methane at 85 billion cubic meters (3.0 trillion cubic feet) annually, or 3% of global production, 3.0 trillion cubic meters or 105 trillion cubic feet (2009 est). Direct emissions of methane represented 14.3% by volume of all global anthropogenic greenhouse gas emissions in 2004.

During extraction, storage, transportation, and distribution, natural gas is known to leak into the atmosphere, particularly during the extraction process. A Cornell University study in 2011 demonstrated that the leak rate of methane may be high enough to jeopardize its global warming advantage over coal. This study was criticized later for its over-estimation of methane leakage values. Preliminary results of some air sampling from airplanes done by the National Oceanic and Atmospheric Administration indicated higher-than-estimated methane releases by gas wells in some areas, but the overall results showed methane emissions in line with previous EPA estimates

Carbon dioxide emissions

Natural gas is often described as the cleanest fossil fuel. It produces 25%–30% and 40%–45% less carbon dioxide per joule delivered than oil and coal respectively, and potentially fewer pollutants than other hydrocarbon fuels. However, in absolute terms, it comprises a substantial percentage of human carbon emissions, and this contribution is projected to grow. According to the IPCC Fourth Assessment Report, in 2004, natural gas produced about 5.3 billion tons a year of CO_2 emissions, while coal and oil produced 10.6 and 10.2 billion tons respectively. According to an updated version of the Special Report on Emissions Scenario by 2030, natural gas would be the source of 11 billion tons a year, with coal and oil now 8.4 and 17.2 billion respectively because demand is increasing 1.9% a year.

Production

Some gas fields yield sour gas containing hydrogen sulfide (H_2S). This untreated gas is toxic. Amine gas treating, an industrial scale process which removes acidic gaseous components, is often used to remove hydrogen sulfide from natural gas.

Extraction of natural gas (or oil) leads to decrease in pressure in the reservoir. Such decrease in pressure in turn may result in subsidence, sinking of the ground above.

Subsidence may affect ecosystems, waterways, sewer and water supply systems, foundations, and so on.

Fracking

Releasing natural gas from subsurface porous rock formations may be accomplished by a process called hydraulic fracturing or "fracking". It's estimated that hydraulic fracturing will eventually account for nearly 70% of natural gas development in North America. Since the first commercial hydraulic fracturing operation in 1949, approximately one million wells have been hydraulically fractured in the United States. The production of natural gas from hydraulically fractured wells has utilized the technological developments of directional and horizontal drilling, which improved access to natural gas in tight rock formations. Strong growth in the production of unconventional gas from hydraulically fractured wells occurred between 2000-2012.

In hydraulic fracturing, well operators force water mixed with a variety of chemicals through the wellbore casing into the rock. The high pressure water breaks up or "fracks" the rock, which releases gas from the rock formation. Sand and other particles are added to the water as a proppant to keep the fractures in the rock open, thus enabling the gas to flow into the casing and then to the surface. Chemicals are added to the fluid to perform such functions as reducing friction and inhibiting corrosion. After the "frack," oil or gas is extracted and 30–70% of the frack fluid, i.e. the mixture of water, chemicals, sand, etc., flows back to the surface. Many gas-bearing formations also contain water, which will flow up the wellbore to the surface along with the gas, in both hydraulically fractured and non-hydraulically fractured wells. This produced water often has a high content of salt and other dissolved minerals that occur in the formation.

The volume of water used to hydraulically fracture wells varies according to the hydraulic fracturing technique. In the United States, the average volume of water used per hydraulic fracture has been reported as nearly 7,375 gallons for vertical oil and gas wells prior to 1953, nearly 197,000 gallons for vertical oil and gas wells between 2000-2010, and nearly 3 million gallons for horizontal gas wells between 2000-2010.

Determining which fracking technique is appropriate for well productivity depends largely on the properties of the reservoir rock from which to extract oil or gas. If the rock is characterized by low-permeability — which refers to its ability to let substances, i.e. gas, pass through it, then the rock may be considered a source of tight gas. Fracking for shale gas, which is currently also known as a source of unconventional gas, involves drilling a borehole vertically until it reaches a lateral

shale rock formation, at which point the drill turns to follow the rock for hundreds or thousands of feet horizontally. In contrast, conventional oil and gas sources are characterized by higher rock permeability, which naturally enables the flow of oil or gas into the wellbore with less intensive hydraulic fracturing techniques than the production of tight gas has required. The decades in development of drilling technology for conventional and unconventional oil and gas production has not only improved access to natural gas in low-permeability reservoir rocks, but also posed significant adverse impacts on environmental and public health.

The US EPA has acknowledged that toxic, carcinogenic chemicals, i.e. benzene and ethylbenzene, have been used as gelling agents in water and chemical mixtures for high volume horizontal fracturing (HVHF). Following the hydraulic fracture in HVHF, the water, chemicals, and frack fluid that return to the well's surface, called flowback or produced water, may contain radioactive materials, heavy metals, natural salts, and hydrocarbons which exist naturally in shale rock formations. Fracking chemicals, radioactive materials, heavy metals, and salts that are removed from the HVHF well by well operators are so difficult to remove from the water they're mixed with, and would so heavily pollute the water cycle, that most of the flowback is either recycled into other fracking operations or injected into deep underground wells, eliminating the water that HVHF required from the hydrologic cycle.

Added odor

In order to assist in detecting leaks, an odorizer is added to the otherwise colorless and almost odorless gas used by consumers. The odor has been compared to the smell of rotten eggs, due to the added tert-Butylthiol (t-butyl mercaptan). Sometimes a related compound, thiophane, may be used in the mixture. Situations in which an odorant that is added to natural gas can be detected by analytical instrumentation, but cannot be properly detected by an observer with a normal sense of smell, have occurred in the natural gas industry. This is caused by odor masking, when one odorant overpowers the sensation of another. As of 2011, the industry is conducting research on the causes of odor masking.

Explosions caused by natural gas leaks occur a few times each year. Individual homes, small businesses and other structures are most frequently affected when an internal leak builds up gas inside the structure. Frequently, the blast is powerful enough to significantly damage a building but leave it standing. In these cases, the people inside tend to have minor to moderate injuries. Occasionally, the gas can collect in high enough quantities to cause a deadly explosion, disintegrating one or more buildings in the process. The gas usually dissipates readily outdoors, but can

sometimes collect in dangerous quantities if flow rates are high enough. However, considering the tens of millions of structures that use the fuel, the individual risk of using natural gas is very low.

Risk of carbon monoxide inhalation

Natural gas heating systems may cause carbon monoxide poisoning if unvented or poorly vented. In 2011, natural gas furnaces, space heaters, water heaters and stoves were blamed for 11 carbon monoxide deaths in the US. Another 22 deaths were attributed to appliances running on liquified petroleum gas, and 17 deaths on gas of unspecified type. Improvements in natural gas furnace designs have greatly reduced CO poisoning concerns. Detectors are also available that warn of carbon monoxide and/or explosive gas (methane, propane, etc.).

European Union

Gas prices for end users vary greatly across the EU. A single European energy market, one of the key objectives of the EU, should level the prices of gas in all EU member states. Moreover, it would help to resolve supply and global warming issues, as well as strengthen relations with other Mediterranean countries and foster investments in the region.

United States

In US units, one standard cubic foot (28 L) of natural gas produces around 1,028 British thermal units (1,085 kJ). The actual heating value when the water formed does not condense is the net heat of combustion and can be as much as 10% less.

In the United States, retail sales are often in units of therms (th); 1 therm = 100,000 BTU. Gas sales to domestic consumers are often in units of 100 standard cubic feet (scf). Gas meters measure the volume of gas used, and this is converted to therms by multiplying the volume by the energy content of the gas used during that period, which varies slightly over time. The typical annual consumption of a single family residence is 1,000 therms or one Residential Customer Equivalent (RCE). Wholesale transactions are generally done in decatherms (Dth), thousand decatherms

(MDth), or million decatherms (MMDth). A million decatherms is a trillion BTU, roughly a billion cubic feet of natural gas.

The price of natural gas varies greatly depending on location and type of consumer. In 2007, a price of $7 per 1000 cubic feet ($0.25/m^3) was typical in the United States. The typical caloric value of natural gas is roughly 1,000 BTU per cubic foot, depending on gas composition. This corresponds to around $7 per million BTU or around $7 per gigajoule (GJ). In April 2008, the wholesale price was $10 per 1000 cubic feet ($10/MMBTU). The residential price varies from 50% to 300% more than the wholesale price. At the end of 2007, this was $12–$16 per 1000 cubic feet ($0.42–$0.57/m^3). Natural gas in the United States is traded as a futures contract on the New York Mercantile Exchange. Each contract is for 10,000 MMBTU or 10 billion BTU (10,551 GJ). Thus, if the price of gas is $10/MMBTU on the NYMEX, the contract is worth $100,000.

Canada

Canada uses metric measure for internal trade of petrochemical products. Consequently, natural gas is sold by the gigajoule (GJ), cubic meter (m^3) or thousand cubic meters (E3m3). Distribution infrastructure and meters almost always meter volume (cubic foot or cubic meter). Some jurisdictions, such as Saskatchewan, sell gas by volume only. Other jurisdictions, such as Alberta, gas is sold by the energy content (GJ). In these areas, almost all meters for residential and small commercial customers measure volume (m^3 or ft^3), and billing statements include a multiplier to convert the volume to energy content of the local gas supply.

A gigajoule (GJ) is a measure approximately equal to half a barrel (250 lbs) of oil, or 1 million BTUs, or 1,000 cu ft or 28 m^3 of gas. The energy content of gas supply in Canada can vary from 37 to 43 MJ/m^3 (990 to 1,150 BTU/cu ft) depending on gas supply and processing between the wellhead and the customer.

Elsewhere

In the rest of the world, natural gas is sold in gigajoule retail units. LNG (liquefied natural gas) and LPG (liquefied petroleum gas) are traded in metric tonnes (1,000 kg) or MMBTU as spot deliveries. Long term natural gas distribution contracts are signed in cubic meters, and LNG contracts are in metric tonnes. The LNG and LPG is transported by specialized transport ships, as the gas is liquified at cryogenictemperatures. The specification of each LNG/LPG cargo will usually contain the energy content, but this information is in general not available to the public.

In the Russian Federation, Gazprom sold approximately 250 billion cubic meters (8.8 trillion cubic feet) of natural gas in 2008. In 2013 they produced 487.4 billion cubic meters (17.21 trillion cubic feet) of natural and associated gas. Gazprom supplied Europe with 161.5 billion cubic meters (5.70 trillion cubic feet) of gas in 2013.

In August 2015, possibly the largest natural gas discovery in history was made and notified by an Italian gas company ENI. The energy company indicated that it has unearthed a "supergiant" gas field in the Mediterranean Sea covering about 40 square miles (100 km^2). It was also reported that the gas field could hold a potential 30 trillion cubic feet (850 billion cubic meters) of natural gas. ENI said that the energy is about5.5 billion barrels of oil equivalent [BOE] (3.4×10^{10} GJ). The field was found in the deep waters off the northern coast of Egypt and ENI claims that it will be the largest ever in the Mediterranean and even the world.

Natural gas as an asset class for institutional investors

Research conducted by the World Pensions Council (WPC) suggests that large US and Canadian pension funds and Asian and MENA area SWF investors have become particularly active in the fields of natural gas and natural gas infrastructure, a trend started in 2005 by the formation of Scotia Gas Networks in the UK by OMERS and Ontario Teachers' Pension Plan.

Adsorbed natural gas (ANG)

Another way to store natural gas is adsorbing it to the porous solids called sorbents. The best condition for methane storage is at room temperature and atmospheric pressure. The used pressure can be up to 4 MPa (about 40 times atmospheric pressure) for having more storage capacity. The most common sorbent used for ANG is activated carbon (AC). Three main types of activated carbons for ANG are: Activated Carbon Fiber (ACF), Powdered Activated Carbon (PAC), activated carbon monolith.

Uranium

Uranium is a chemical element with symbol **U** and atomic number 92. It is a silvery-white metal in the actinide series of the periodic table. A uranium atom has 92 protons and 92 electrons, of which 6 are valence electrons. Uranium is weakly radioactive because all isotopes of uranium are unstable, with half-lives varying between 159,200 years and 4.5 billion years. The most common isotopes in natural uranium are uranium-238 (which has 146 neutrons and accounts for over 99%) and uranium-235 (which has 143 neutrons). Uranium has the highest atomic weight of the primordially occurring elements. Its density is about 70% higher than that of lead, and slightly lower than that of gold or tungsten. It occurs naturally in low concentrations of a few parts per million in soil, rock and water, and is commercially extracted from uranium-bearing minerals such as uraninite.

In nature, uranium is found as uranium-238 (99.2739–99.2752%), uranium-235 (0.7198–0.7202%), and a very small amount of uranium-234 (0.0050–0.0059%). Uranium decays slowly by emitting an alpha particle. The half-life of uranium-238 is about 4.47 billion years and that of uranium-235 is 704 million years, making them useful in dating the age of the Earth.

Many contemporary uses of uranium exploit its unique nuclear properties. Uranium-235 is the only naturally occurring fissile isotope, which makes it widely used in nuclear power plants and nuclear weapons. However, because of the tiny amounts found in nature, uranium needs to undergo enrichment so that enough uranium-235 is present. Uranium-238 is fissionable by fast neutrons, and is fertile, meaning it can be transmuted to fissile plutonium-239 in a nuclear reactor. Another fissile isotope, uranium-233, can be produced from natural thorium and is also important in nuclear technology. Uranium-238 has a small probability for spontaneous fission or even induced fission with fast neutrons; uranium-235 and to a lesser degree uranium-233 have a much higher fission cross-section for slow neutrons. In sufficient concentration, these isotopes maintain a sustained nuclear chain reaction. This generates the heat in nuclear power reactors, and produces the fissile material for nuclear weapons. Depleted uranium(^{238}U) is used in kinetic energy penetrators and armor plating. Uranium is used as a colorant in uranium glass, producing lemon yellow to green colors. Uranium glass fluoresces green in ultraviolet light. It was also used for tinting and shading in early photography.

The 1789 discovery of uranium in the mineral pitchblende is credited to Martin Heinrich Klaproth, who named the new element after the recently-discovered

planet Uranus. Eugène-Melchior Péligot was the first person to isolate the metal and its radioactive properties were discovered in 1896 by Henri Becquerel. Research by Otto Hahn, Lise Meitner, Enrico Fermi and others, such as J. Robert Oppenheimerstarting in 1934 led to its use as a fuel in the nuclear power industry and in *Little Boy*, the first nuclear weapon used in war. An ensuing arms race during the Cold War between the United States and the Soviet Union produced tens of thousands of nuclear weapons that used uranium metal and uranium-derived plutonium-239. The security of those weapons and their fissile material following the breakup of the Soviet Union in 1991 is an ongoing concern for public health and safety.

Applications

Military

The major application of uranium in the military sector is in high-density penetrators. This ammunition consists of depleted uranium (DU) alloyed with 1–2% other elements, such as titanium or molybdenum. At high impact speed, the density, hardness, and pyrophoricity of the projectile enable the destruction of heavily armored targets. Tank armor and other removable vehicle armor can also be hardened with depleted uranium plates. The use of depleted uranium became politically and environmentally contentious after the use of such munitions by the US, UK and other countries during wars in the Persian Gulf and the Balkans raised questions concerning uranium compounds left in the soil .

Depleted uranium is also used as a shielding material in some containers used to store and transport radioactive materials. While the metal itself is radioactive, its high density makes it more effective than lead in halting radiation from strong sources such as radium. Other uses of depleted uranium include counterweights for aircraft control surfaces, as ballast for missile re-entry vehicles and as a shielding material. Due to its high density, this material is found in inertial guidance systems and in gyroscopic compasses. Depleted uranium is preferred over similarly dense metals due to its ability to be easily machined and cast as well as its relatively low cost. The main risk of exposure to depleted uranium is chemical poisoning by uranium oxide rather than radioactivity (uranium being only a weak alpha emitter).

During the later stages of World War II, the entire Cold War, and to a lesser extent afterwards, uranium-235 has been used as the fissile explosive material to produce nuclear weapons. Initially, two major types of fission bombs were built: a relatively simple device that uses uranium-235 and a more complicated mechanism that uses plutonium-239 derived from uranium-238. Later, a much more complicated and far more powerful type of fission/fusion bomb (thermonuclear weapon) was built, that

uses a plutonium-based device to cause a mixture of tritium and deuterium to undergo nuclear fusion. Such bombs are jacketed in a non-fissile (unenriched) uranium case, and they derive more than half their power from the fission of this material by fast neutrons from the nuclear fusion process.

Civilian

The main use of uranium in the civilian sector is to fuel nuclear power plants. One kilogram of uranium-235 can theoretically produce about 20 terajoules of energy (2×10^{13} joules), assuming complete fission; as much energy as 1500 tonnes of coal.

Commercial nuclear power plants use fuel that is typically enriched to around 3% uranium-235. The CANDU and Magnox designs are the only commercial reactors capable of using unenriched uranium fuel. Fuel used for United States Navy reactors is typically highly enriched in uranium-235 (the exact values are classified). In a breeder reactor, uranium-238 can also be converted into plutonium .

Pre-discovery use

The use of uranium in its natural oxide form dates back to at least the year 79 CE, when it was used to add a yellow color to ceramic glazes. Yellow glass with 1% uranium oxide was found in a Roman villa on Cape Posillipo in the Bay of Naples, Italy, by R. T. Gunther of the University of Oxford in 1912. Starting in the late Middle Ages, pitchblende was extracted from the Habsburg silver mines in Joachimsthal, Bohemia (now Jáchymov in the Czech Republic), and was used as a coloring agent in the local glassmaking industry. In the early 19th century, the world's only known sources of uranium ore were these mines.

Resources and reserves

It is estimated that 5.5 million tonnes of uranium exists in ore reserves that are economically viable at US$59 per lb of uranium, while 35 million tonnes are classed as mineral resources (reasonable prospects for eventual economic extraction). Prices went from about $10/lb in May 2003 to $138/lb in July 2007. This has caused a big increase in spending on exploration, with US$200 million being spent worldwide in 2005, a 54% increase on the previous year. This trend continued through 2006, when expenditure on exploration rocketed to over $774 million, an increase of over 250% compared to 2004. The OECD Nuclear Energy Agency said exploration figures for 2007 would likely match those for 2006.

Australia has 31% of the world's known uranium ore reserves and the world's largest single uranium deposit, located at the Olympic Dam Mine in South Australia. There is

a significant reserve of uranium in Bakouma a sub-prefecture in the prefecture of Mbomou in Central African Republic.

Some nuclear fuel comes from nuclear weapons being dismantled, such as from the Megatons to Megawatts Program.

An additional 4.6 billion tonnes of uranium are estimated to be in sea water (Japanese scientists in the 1980s showed that extraction of uranium from sea water using ion exchangers was technically feasible). There have been experiments to extract uranium from sea water, but the yield has been low due to the carbonate present in the water. In 2012, ORNL researchers announced the successful development of a new absorbent material dubbed HiCap which performs surface retention of solid or gas molecules, atoms or ions and also effectively removes toxic metals from water, according to results verified by researchers at Pacific Northwest National Laboratory.

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